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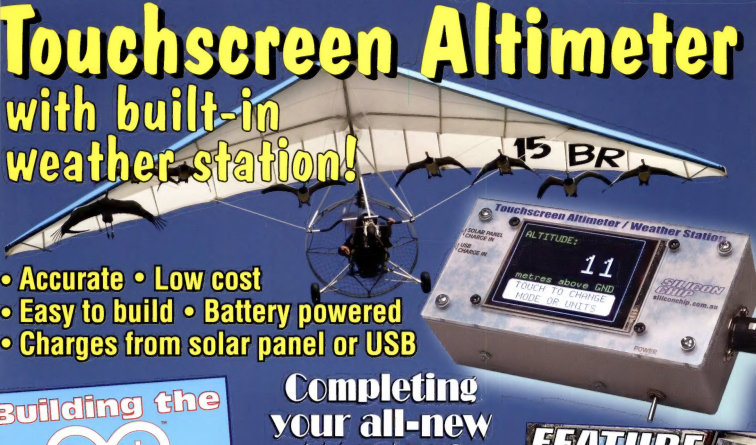

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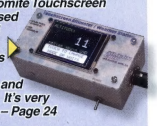

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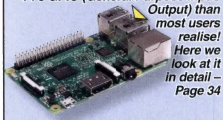

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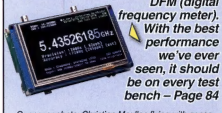

If you only build one piece of test gear this year (or next!) make it the outstanding 6GHz(+) touchscreen DFM (digital frequency meter). With the best performance we've ever seen, it should be on every test bench – Page 84

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Editorial Viewpoint

Australia's strength in manufacturing

The recent closure of the Holden plant in Elizabeth, Victoria, rightly received a lot of media attention. The end of Australian mass-market automotive manufacturing (with the Toyota and Ford plants having already closed) is undoubtedly a disruption to the Australian economy, with a large personal impact on those who have had to find new jobs.

It is likely to have an impact on our local electronics manufacturing industry too. The vehicles made in the now-closed plants contained up to 70% locally-made parts – a lot of it involving electronics.

Hopefully, those suppliers will be able to continue operation as there are still companies making specialised vehicles for the mining industry, the military and off-road market. As well, many of those suppliers are active overseas.

But there is another reason why we've mentioned the automotive plant closures; they echo the closures of large consumer electronics factories in Australia, following the abrupt tariff reductions by the Whitlam government in 1975. Prior to that time, virtually all consumer electronics products, such as radios, stereograms, TVs and car radios, along with all whitegoods were protected by high tariff walls. They have all gone – the last locally-built fridge was made quite recently, with the Electrolux factory in Orange, NSW closing in November 2016.

One of the largest radio and TV manufacturers in Australia, AWA, shut down its last factory in the early 90s. And they didn't just put together electronics from parts made overseas either. From the 40s to the 70s, when local manufacturing was strong, just about all the electronic components parts were made in Australia and in many cases, in the same factory as final assembly took place. Those halcyon days, when consumer electronics products were a great deal more expensive than today, are long gone.

But Australia today still has a substantial electronics industry and it is lean and efficient, as it has to be to compete on world markets. Areas where Australian electronics manufacturers find success include mining tools, medical equipment, sound reinforcement, traffic control, industrial process control and more. And many of these companies are well-regarded around the world and in many cases are market leaders.

You may also be unaware that there are at least 20 electronics assembly facilities in Australia, some of them large and using advanced technology.

Don't believe us? In New South Wales alone we're aware of Circuitwise, GPC Electronics, Nesstronics, Pritchard, On-Track, Soltronico and Wavetronics. In Victoria there's Alfatron, Duet Electronics, Extel and Sniper Electronics; Queensland has Circuit Solutions, Crystalaid, Hetech, Masters & Young and RFTech; South Australia has Entech and TCM Electronics while in Western Australia there's Advanced Technology & Manufacturing, Lyntel and PCB Assembly. These companies would only exist if they had a significant number of customers. And that doesn't include the Australian-based design houses which have their equipment fabricated off-shore.

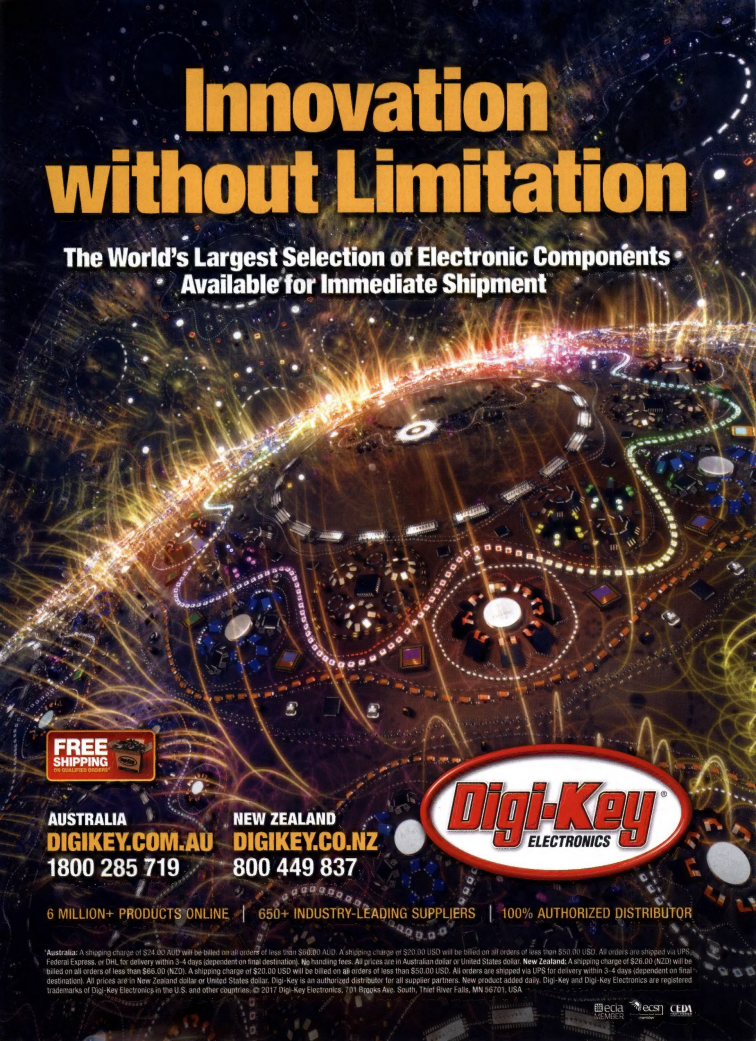
Successful Australian electronics manufacturers include Aldridge Traffic Systems, Blackmagic Design, Codan, Exablaze, Metamako, Radixon, Redarc, Redback Audio and Vix Technology.

And let's not forget companies like Melbourne-based Versatile Technology, (featured in our January 2016 issue). The equipment they design and make for testing drink bottles and cans is exported worldwide.

Undoubtedly, there are many more Australian electronics companies, large and small, which we don't hear about, which are not only providing employment but contributing strongly to our GDP.

You won't hear about them in local media but they are out there, doing well while competing in a very tough environment.

Nicholas Vinen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Congratulations for 30 Years of SILICON CHIP

I have just read Ross Tester's review of SILICON CHIP's last 30 years and was particularly interested in the circumstances that led to the foundation of your publication.

During my 30-year experience as Australian Engineering Manager and global engineering consultant for BP Solar, I found an abundance of stupidity and arrogance in large corporations, particularly within British Petroleum.

Your outstanding success in Australian and global electronics publishing warms my heart. I still have fond memories of working with Leo Simpson, Jim Rowe, Bob Flynn and others, during my short stint with Electronics Australia, prior to April 1970. Wishing you every future success.

Anthony Leo,
Cecil Park, NSW.

Details of the radars used to track WRESAT

I read the article you published on WRESAT in the October issue (**www.siliconchip.com.au/Article/10822**) and thought you might like to take a look at two related pieces which I authored. They are located on Colin Mackellar's Honeysuckle Creek tracking station site.

The first describes the AN-FPS16 radar which was mentioned in the WRESAT article and is found at **www.siliconchip.com.au/link/aaga** Once this page loads, click on the link titled "About the FPS-16 Radar"

The second article describes the AN-FPQ6 radar at the Carnarvon tracking station and is located at **www.siliconchip.com.au/link/aagb** Click on the link titled "The FPQ6 radar".

There is a description by Hamish Lindsay; scroll down to find the description of the radar I wrote.

Ken Anderson,
Sale, Vic.

Neo-7M module with 1pps output is available

I am writing regarding your October 2017 El Cheapo Modules article on the two GPS receivers (**siliconchip.com.au/Article/10827**). It indicates that the u-blox Neo-7M module does not have a 1pps (one pulse per second) output. But there is a different version of the Neo-7M module that does provide a 1PPS output.

It is available from eBay and sells for US$7.85. See: **www.ebay.com/itm/311876309386** In addition to an SMA input port for an external active antenna, this module has a passive antenna mounted on the rear of the PCB. It also has a micro-USB interface (in addition to UART connections).

Using the external antenna port, the sensitivity seems to be better than the Neo-6M module that I have.

Trevor Woods,
Auckland, NZ.

Limiting water heater power for solar installation

I have a suggestion regarding the question titled "Limiting hot water power to suit solar system" in the Ask SILICON CHIP section of the October issue, on page 96.

Birthday wishes from our biggest supporter

Dear Leo & SILICON CHIP staff,

On behalf of all at Jaycar, I would like to congratulate you on the 30th anniversary of your first issue. That milestone seems to have snuck up!

I can remember like it was yesterday when you first started. I had no doubt that you would be successful and Jack O'Donnell (owner of Altronics) felt the same.

And yes, the magazine has seen a profound change in the way the world works. You actually started before the rise of the internet but now almost everything works within its context.

I still look forward to my monthly read of "SILICON CHIP" for despite everything else, I am still an electronic enthusiast and do appreciate the clarity of the text, illustrations and diagrams that you work so hard to keep to a high standard.

Once again, a note of thanks from all of us at Jaycar. Cheers!

Gary Johnston,
Managing Director,
Jaycar Electronics Group.

Did we forget to mention someone important?

I just received my November copy of SILICON CHIP today and noted the reason for well-deserved celebrations. Congratulations on achieving 30 years of quality publication and outstanding technical journalism over what must have been some very difficult patches.

I noted that your editorial did not mention Jim Rowe for some reason. I trust he is in good health and the lack of any special mention was just a simple editorial slip-up! Wishing you all the best for the future...

Owen Hill,
Rutherford, NSW.

Leo responds: Jim Rowe is alive and kicking and working full-time for SILICON CHIP. In fact, Jim has worked for SILICON CHIP virtually since EA folded – I did not want his know-how to go to waste.

Of course, other past EA staffers worked for SILICON CHIP in the early years, including ex-editor Neville Williams, ex-assistant editor Philip Watson, and in more recent years, Maurie Findlay (all now deceased).

More recently we have had our Induction Motor Speed Controller (2012) designed by past EA-staff member Andrew Levido and other staff members have made smaller contributions. Finally, Ross Tester also worked at EA in the past and came to SILICON CHIP in 1995.

One way of using your limited power to boost your hot water is to use a twin element hot water tank.

The bottom element can be left as-is but the top element can be replaced with a 2kW element which can be run from solar power during the day, when sun shines. When the sun does not shine, a contactor could be used to connect it back to the mains.

David Haddock,
Bethania, Qld.

Note: Not all hot water tanks have booster elements but many do have provisions for such an element.

Preventing corrosion in solar-boosted hot water systems

Thanks for your articles about connecting your solar panels to an electric hot water tank. The most recent article left me with the impression it was too hard to do as over time a DC current would result in corrosion of the electric element, an AC supply being required to prevent this.

The frequency of 50Hz alternating current is arbitrary. Would a 1Hz supply work? What about simply swapping the polarity of the DC at the end of each day?

Does anyone have any knowledge on the most effective period to prevent corrosion? I might try it on my kettle as I don't think its any different to an electric hot water tank.

Hamish Rouse,
Mt Martha, Vic.

Response: you are quite right that the polarity doesn't need to reverse at 50Hz. However, the problem with a 24-hour period is that the total current flow from one period to the next could be quite different, meaning that you could still have a DC current flow on average. Also, it's possible that too much corrosion could occur in a 24-hour period for it to easily be reversed in the next 24-hour period.

So we would suggest a shorter period than this, although 1Hz would probably be OK, or even a somewhat lower frequency. A relay swapping the element polarity every few minutes would probably do the trick but you would have to make sure the relay could handle switching the (potentially) high DC current or it wouldn't last long.

Serviceman story a reminder of a nice, easy repair

I liked the Serviceman story regarding the repair of a MIG welder.

Some time ago, I needed an AC TIG welder to weld aluminium. These things are not cheap but I found a second-hand unit in the Hunter where the AC function had failed but the DC function (for welding steel) was still working. I bought it thinking that it's only electronics so it should be easy to fix.

Getting it back to Canberra I opened it up to start the repair. I couldn't see most of the control board (with TTL components) for all the grinding dust.

I blew out the unit with compressed air. I then tested it again and the AC function worked. It was the simplest electronic repair I have ever done!

Garry Woods,
Canberra, ACT.

BackPack problems may be due to bad LCD pin connections

I just read the letter titled "Pain in the BackPack" from M. L., on page 97 of Ask Silicon Chip, in the October 2017 issue. I had the same problem after building the Micromite Plus LCD BackPack kit.

In my case, it was caused by a faulty through-hole connection on the PCB at the CON3 LED pin. The solution was to solder the pin on the top side, after cutting away a little of the socket strip plastic.

I then also found the touch feature didn't work. This turned out to be the same problem and was cured with the same fix on the CON3 T_CLK pin.

Playing around with the Micromite has been a great learning experience.

I also had a problem getting stable analog input readings (from a thermistor via a resistive voltage divider). Adding an RC low-pass filter at the input didn't help.

Replacing the 5V switchmode supply with a linear 5V regulator fed from 12V battery only made a small improvement. Increasing the LCD backlight switching frequency from 200Hz to 2000Hz greatly reduced the noise.

Want to work for Australia's Electronics Magazine

SILICON CHIP

If you live, breathe and sleep electronics you could be just the person we're looking for. While formal qualifications are well regarded, don't let a lack of letters after your name put you off, if you have the experience we're looking for.

The right person will certainly have skills in the following areas:

- ☑ **Analog and digital circuit design from concept to completion**
- ☑ **Circuit analysis and debugging**
- ☑ **PCB layout (we use Altium Designer)**
- ☑ **PC software development and embedded programming**
- ☑ **Operating electronic test equipment**
- ☑ **Mechanical design**

But most of all, you'll have the ability to write interesting articles (in English) describing what you've built and how SILICON CHIP readers can reproduce what you've done. You will have seen the style of SILICON CHIP articles – you're almost certainly an existing SILICON CHIP reader.

If you have skills in other areas which would help SILICON CHIP appear each month, tell us about them too: skills such as sub-editing, desktop publishing/layout, circuit drawing, photography, image processing, technical support/customer service (via telephone), project management, parts ordering and management, database administration, website design/programming and operating CNC equipment.

We don't expect you to have all these skills – but we'll help you to develop them as required.

You'll need to be highly self-motivated and able to work well by yourself as well as in a small team. Being able to work to the rigorous deadlines of a monthly magazine is vital.

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Perhaps digital currents are adding noise to analog AV_{DD} or AV_{SS} (IC1 pins 19 & 20). Increasing the capacitor value between these pins from 100nF to 10µF and soldering a wire to each end of it to provide analog power and ground to the thermistor's resistive voltage divider totally cured it.

On the next Micromite PCB revision, similar analog power and ground header pins could be added. Also, the PCB design methods you use for your outstanding audio amplifiers may help.

A temporary software solution is to read the analog input many times and take the average. It slows things down but it works. For example:

```
SETPIN 22, AIN : SETPIN 23, AIN :
  SETPIN 24, AIN

PRINT AnalogSample(22),
  AnalogSample(23),
  AnalogSample(24)

FUNCTION
  AnalogSample(InputPin)
  LOCAL Vin = 0
  LOCAL INTEGER Sample
  For Sample = 1 to 1000
  Vin = Vin + Pin(InputPin)
  Next
  'multiplication faster than division
  AnalogSample = Vin * 0.001
EndSub
```

Response: soldering the pins on the top layer of the board should not be necessary and this suggests a failure of the through-hole plating which is not good.

Modern PCB quality is high and we're very surprised to hear of this kind of manufacturing fault, especially since most PCBs now go through an electrical testing procedure before they are sent out.

As you've discovered, the only way to reduce analog reading noise to a reasonable level is to connect the analog sensor grounds directly to the AGND pin.

Since this is internally connected to digital ground in the PIC chip, we can't run separate analog and digital ground tracks. The Backpack is a general purpose board so compactness was prioritised over analog reading accuracy.

It would be a good idea to have a separate analog ground connection on microcontroller boards. But generally speaking, if you need accurate measurements, it's easier to connect a separate analog-to-digital converter board to the PIC via an SPI bus and this will not only allow you to separate out the digital noise but it will likely also provide better resolution and more inherent accuracy.

For example, breakout boards for the AD7793 24-bit low-noise ADC are available for less than $10 and offer much better performance than the typical 10-bit ADC in a PIC.

Useful tip gleaned from Serviceman

I was just reading the Serviceman's Log the other day and Dave's tip about cutting the slot in the Torx bit, in order to remove a recessed screw, proved to be very useful.

My pressure cleaner was leaking and I wanted to dismantle it to see what the problem was, so Dave's tip solved the issue of the three inaccessible screws.

Unfortunately, the pressure cleaner is a write-off, due to the specialised parts being unavailable but at least I was able to find what the problem was. I have already emailed him and told him how useful his suggestion was.

Has Leo stepped down as Editor, or is he just on long service leave? He's been the Editor of SILICON CHIP since day one and it's a bit different seeing Nicholas as Editor.

I've been collecting SILICON CHIP magazines over the last few years and I think I now have almost all the issues, although I still have some issues to check for missing pages.

However, I have not been able to find a copy of the February 1988 issue. Hopefully, one will show up sometime, but it could be rare now.

Bruce Pierson,
Dundathu, Qld.

Response: If you check page two of the January 2017 issue, you will see that Nicholas has been listed as the Editor for some time now.

Leo Simpson is still the Publisher although it remains to be seen how much longer he will stay in that role.

If you look up the date of his early articles in Electronics Australia (in 1967), you will see that he has been in the magazine business for a long time!

Unfortunately, while we keep back issues in stock for some time, we tend to discard them after about 20 years due to minimal demand.

The earliest back issue that we have in stock is January 1997. We imagine quite a few readers would still have a copy of the February 1998 issue though.

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Wall mountable with radiation shield. Range: -40~60°C and 0-100%RH. RS485 Modbus RTU output.
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NBN modem rebooter circuit was unnecessarily complex

Following the recent publication of the automatically rebooting NBN modem in the Circuit Notebook section of SILICON CHIP, September 2017 (**www.siliconchip.com.au/Article/10785**).

Please see above a picture of my low-tech device that does the same thing. It too de-powers the NBN modem at 3:00am each morning but it doesn't re-power it until 15 minutes later.

This is a disadvantage compared to your published design but I can live with the 15-minute downtime at that time of the morning. My approach has no Micromites, no SMDs, no firmware, no software and is ultra-reliable.

However, the way things are going with electricity in this country, neither approach may be needed much longer. There may just be enough blackouts to re-set NBN modems frequently.

Thanks for the great magazine.
Jim McLellan,
via email.

Response: your approach is commendably simple but does have the disadvantage that the reset time will change if there is a blackout and you may not notice it straight away. The published circuit does at least have a backup battery.

We agree it's overly complex for the job it does but we purposefully published it as-is since that was the approach the author took and there were some interesting aspects to the design.

November issue enjoyed

Today I received my hard copy edition of this magazine; it's a great read. I think the article on Making Phone Calls via Satellite is awesome. And the 30 years article is great as well – how the years have gone by!

I still insist on reading the printed version rather than online. I like to give my eyes a "digital detox" away from the screen and read a physical magazine for a change.

It is certainly a magazine I look forward to receiving in my PO Box once a month. Thanks again for a great magazine.

Peter Casey,
West Pennant Hills, NSW.

Comments on Digital Radio Mondiale and history of AM stereo

As a keen radio and shortwave listener over many years, I found the two articles on DRM, on pages 61 and 63 in the September issue of SILICON CHIP to be of great interest (**www.siliconchip.com.au/Article/10797** and **www.siliconchip.com.au/Article/10798**).

They brought to mind several debacles in both Australia and New Zealand in the area of broadcasting.

In New Zealand in the 1970s, with consumer AM/FM receiving equipment becoming available due to small numbers of imports and overseas travellers returning with portable and hifi equipment, there was pressure on government to permit the establishment of FM broadcasting. However, it did not commence until 1982.

Part of the reason for delaying its introduction was that the 88-108MHz band was to a large extent used for the Land Mobile Service which meant that a shift of this service to other frequency bands was necessary.

That came with the consequent cost and delays in implementing the new base stations and mobile equipment required.

What this indicated was a lack of planning for future changes and public demand and pressure for a service which existed in many other parts of the world using this frequency band.

In Australia, 1985 was the year that AM stereo was introduced. However, in its wisdom, the government had decided to allow all four systems available to be licensed and let the market decide on the ultimately successful system. This was the same strategy adopted by the FCC in the USA.

The FCC eventually made the Motorola C-QUAM system the standard. In Australia, AM Stereo was never going to be a success due to the size of the country with such relatively small and widely spaced population and with low quantities of suitable equipment available. So AM stereo here died a slow death.

As far as the closing of Radio Australia is concerned, yes, it is unfortunate, however, the ABC has been so starved of funds by successive governments over time that they need to make every dollar count, especially as they have to invest in ever-changing technology in order to remain a leader in the area of broadcasting.

Nevertheless, I am in support of a reinstatement of Radio Australia and the three internal shortwave services. A different funding model needs to be found whereby a separate allocation by government for the service is made available, possibly via the Foreign Affairs and Aboriginal Affairs departments.

And now looking to the future of broadcasting. In the case of the expansion of DAB+ services, it would appear from the table on page 62 of the September 2017 issue that a number of the regional areas with large populations are not about to have a DAB+ service any time soon.

Canberra and Darwin have had a trial DAB+ service for some years using Channel 10B, which is now to be upgraded to a new service using Channels 9A and 9B.

As for the implementation of services using DRM, the ACMA website states that "DRM is unlikely to be a viable option in the short to medium term in Australia as there are only a few receivers currently available in the market.

In addition, the prospect of dual DAB and DRM receivers being introduced into the Australian market is low". So I guess that statement says it all, it is not under consideration.

Personally, having had experience of listening to DRM transmissions from several broadcasters, I must say that unless the signal-to-noise ratio is good, the transmission will not be decoded and the audio will drop out.

This is the case even though the station can still be seen on the waterfall display and the signal strength meter. It is sort of like using a mobile phone in a poor area where the signal just drops out.

So for now, in my area (the Hunter Valley), I will continue to use the existing AM and FM stations. The quality of the FM broadcasts is pretty good, depending on program material and from what I have, read it may be better than DAB+.

Thank you for an interesting and thought-provoking publication.

Richard Kerr,
Cessnock, NSW.

Comment: the statement from ACMA sounds like a chicken-and-egg argument. Of course there won't be many radios in Australia capable of receiving DRM if there are no DRM broadcasts.

The same could have been said of DAB/DAB+ just a few years ago. We agree with you that good FM stations can provide better sound quality than DAB+. The digital compression is just too severe for it to be hifi.

Nothing new under the sun when it comes to heating water

I saw your article on adjusting hot water heater thermostats in the October 2017 issue (**www.siliconchip.com.au/Article/10834**).

You may be interested in doing an article on an Australian company called Microheat.

They developed and own the patent for an "instantaneous" electric hot water technology which basically involves zapping the hot water with electricity. See **http://mams.rmit.edu.au/xogcg47u4b2s.pdf** and **www.microheat.com.au/the-technology**

Basically, it zaps the water to 30~50°C instantaneously with minimal standby power.

Joseph Goldburg,
Dingley Village, Vic.

Response: That "instantaneous" hot water heating system is neither new nor instantaneous. The heating "element" consists of two plates immersed

in the water and the plates have the full 230VAC applied to them.

The water is heated up as it passes between the plates. Any heating effect relies on mineralisation (ie, salts) in the water to provide some conduction.

Despite the name, it does not use microwave heating. Nor will it work on water which is very pure or distilled. So rainwater or water which is very soft will not be able to be heated effectively or will take a very long time to heat.

The rate of heating will depend solely on the amount of heat which can be pumped into the water and the rate at which the water passes between the plates.

Unless the metal plates are very large (and close together) the heating effect is likely to be slower than in a tank with a conventional resistive heating element. Nor is this method of heating any more efficient than with resistive elements.

This is not to say that this system of heating will not work. It clearly will work but the heating effect will be fairly modest and at low flow rates.

Finally, this system of heating was used over 70 years ago in electric jugs. The "element" consisted of two closely-spaced metal discs. This had the advantage that the heating element would not burn out if it was not fully immersed but they were slower to boil water than jugs with a resistive element.

Printed back issues take up too much space

I have been buying SILICON CHIP for many years and I am sure like many other readers have quite a stash of back issues.

With plans afoot to move interstate at the end of the year, I have started the process of looking around the shed to see what will make the cut into the moving box. Unfortunately, 15 years worth of back issues won't make it.

I do find myself occasionally looking up back issues for old projects, but not enough to justify keeping them all. Has there been any thought about digitising the old issues of SILICON CHIP and making the archive available for purchase?

Circuit Cellar and Elektor both allow you to purchase a complete archive or access back issues as PDF files through the website.

I think this might also be a good way around the issue Pete Mundy brought up in the October letters page about the upcoming demise of Flash. By having full PDF issues on the website each month you remove the need to manage the individual projects.

By adding a digital watermark to the files you could link them with the email address of the original purchaser allowing you to track where they come from should issues start appearing on pirate sites.

While I offer the suggestion as food for though I am currently going through the process of looking through each magazine and removing the pages with any articles of interest with the intention to scan them and make my own PDF copy for personal use.

Bill Coghill
Ramsgate, NSW.

Response: we would love to offer PDF downloads but we lack the resources to police the already rife copyright violations which cost us money.

Magazine sales are a large proportion of our revenue and without them, the magazine will fold (no pun intended). We expect that if we offered PDFs, the problem would just get worse, regardless of watermarking.

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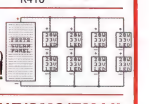

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Hifi Radio Receiver would be appreciated

With reference to the letter "Modern hifi radio receiver design desired" in the Ask Silicon Chip section of the October 2017 edition of SILICON CHIP, I too live in the country and would be very interested in such a project.

As always I look forward to each edition of SILICON CHIP – it's an excellent magazine. My particular interest is in the Micromite projects.

David Hebblethwaite,
Maleny, Qld.

Problem with programmed chips for 50A Charger Controller

I have a need to charge a battery from a vehicle to run some radio equipment.

I purchased the 50A Charger Controller PCB (November 2016; siliconchip.com.au/Article/10413) and pre-programmed microprocessor from SILICON CHIP and the other items from my local Jaycar store.

Assembly and checkout went smoothly and I verified that all components were the correct value. I noticed some discrepancies between the circuit diagram (Fig.3 on page 35) and the PCB, for example, D4's cathode actually connects to the battery + terminal, not JP1 as shown on the circuit.

I'm not quite sure how D4 protects the board if the battery is connected in reverse as either the PCB track will vaporise or the diode would fail due to over-current.

I powered the unit up using a bench supply for testing and varied the voltage up and down. I confirmed that pin 6 on IC1 was varying in voltage from 3.2 to 4.5V but neither relay was switching.

I figured it might be a dud microcontroller so I purchased another one from SILICON CHIP and had the same result.

I had a friend check both microcontrollers out but they seemed to be blank. I then had him download the software from your website and program them. Imagine my surprise when the unit then worked!

Please check your stock of pre-programmed chips and confirm that they are really programmed.

Also, the circuit description on page 35 states "it switches on transistor Q1 to activate relay RLY1 and interrupt the charge" ...it should say "it switches OFF transistor Q1 to deactivate RLY1 and interrupt the charge".

The circuit also has a flaw in that if the battery voltage falls below the supply dropout voltage of REG2, the charger will never be connected to the battery to charge it.

Paul A. Smith,
Engadine, NSW.

Response: we're sorry that you received apparently blank chips and we are quite surprised by this. We did check the programmed chips we have remaining in stock for that project and they are all correctly programmed.

However, they were probably programmed at a different time from the ones we sent you. We will refund what you paid for the chips and software.

You are right that there is an error in the PCB design regarding diode D4. We will publish an errata and design a revised board which we will order when the existing stock runs out.

It would be worthwhile cutting the track between the anode of D4 and the adjacent 100kΩ resistor and soldering a short wire from there to the opposite end of that resistor, so that it provides proper protection to the circuit.

You are also correct about the circuit caption being wrong. However, we don't agree with your statement that "The circuit also has a flaw in that if the battery voltage falls below the supply dropout voltage of REG2 the charger will never be connected to the battery to charge it."

If the battery drops below 12V, the output of REG2 will simply be the battery voltage minus REG2's dropout voltage, which is a fraction of a volt.

The relay will still operate down to below 9V. If your battery is discharged down to below 9V, it would be advisable to slowly bring the battery up in voltage with a low current charge rather than the high current available via the charger controller.

Besides, a lead-acid battery that has been discharged to 9V will normally have severely reduced capacity due to sulfation and will probably require replacement.

Sophisticated radio design desired

I read the letter titled "Modern hifi AM radio receiver design desired" on pages 99-100 of the October issue, in the Ask Silicon Chip section. I too have thought about building the February-April 1991 AM Tuner design myself but realised most of the parts are no longer available.

I have made enough simple AM and FM radio projects that I would like to build something more sophisticated. I would prefer a design which included not just AM and FM but also LW and SW which are still used in Europe.

Silicon Labs have the "SiXXXX" range of radio chips that could be used. I noticed that one of the sets includes DAB radio as well. I know you had a FM/DAB radio project a while back but that was based on a ready-made module.

Jeff Dunn,
Auckland, New Zealand.

Response: we will consider a radio design based on the Si4685 IC but such a project would require extensive software development and could take many months to produce.

We also wonder whether it would end up being more expensive to build than an equivalent commercial product, such as the Jaycar AR1946 receiver which has all the features you've asked for.

Another request for a comprehensive radio design

I would like to see you design a multi-band AM/FM radio using an Si4735 IC. The radio could receive LW, MW, SW and FM (depending which IC version is chosen). Tuning would be simple using two up/down buttons plus one band change button. Stereo on FM would be nice.

The advantage of this IC is than no alignment is needed. The audio amplifier could be Class-D and capable of around 10W/channel.

You could use a pre-built module. These are so cheap, you could not buy a volume control pot for the cost of the amplifier module.

Maybe for a future radio, DAB+ could be added and the ability to play MP3 or WAV files when radio reception (or programming) is poor. It could run from three 18650 batteries (with its own internal charger).

These days, I find it hard to keep up with newer technologies, I don't know how you do it.

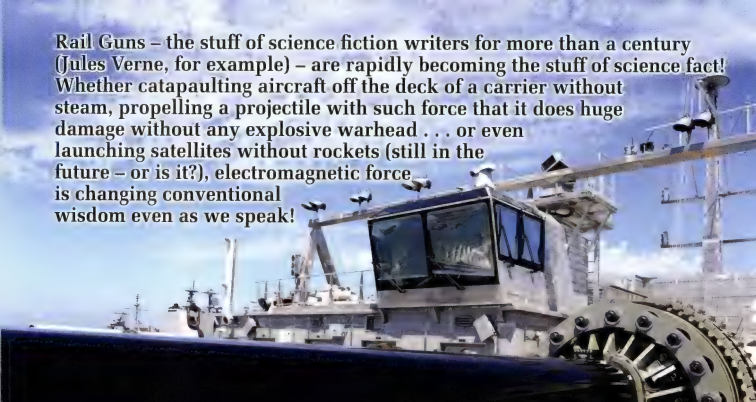
Rod Humphris,
Ferntree Gully, Vic.

Comment: as per the response above, if we did this, we would use the Si4685 in order to have DAB+ reception in addition to FM, AM, SW and LW.

We wonder how many people will build the radio given that the chips are only available in leadless SMD packages.

These certainly can be hand-soldered but some care is required. 18650 cells are problematic (there are a lot of dodgy ones around); perhaps a LiPo pack would be a better solution. SC

Rail Guns – the stuff of science fiction writers for more than a century (Jules Verne, for example) – are rapidly becoming the stuff of science fact! Whether catapaulting aircraft off the deck of a carrier without steam, propelling a projectile with such force that it does huge damage without any explosive warhead . . . or even launching satellites without rockets (still in the future – or is it?), electromagnetic force is changing conventional wisdom even as we speak!



Rail Guns and Electromagnetic Launchers

By Dr David Maddison

There is a surprisingly long history behind electromagnetic launchers, going back to the mid-19th century.

In 1844, a Mr Benningfield (first name unknown) invented an electric gun called the SIVA or Destroyer but little is known of what became of it as there was no further mention of it after 1844.

An advertisement for a demonstration of the device said "*Officers consider that this invention will, in great measure, supersede Gunpowder, and say that it is very much more to be feared than any Engine of War in use.*

The balls were projected in a continuous stream at a rate of more than 2,000 per minute, each ball having force enough to kill at a greater distance than a mile with certain aim, and continue from year to year at a cost far less than gunpowder, although with more force.".

In 1845, in The American Journal of Science and Arts, October edition (page 132), Charles G. Page described a "magnetic gun" in which "*Four or more helices arranged successively, constitute the barrel of the gun, which is mounted with a stock and breech. The bar slides freely through the helices, and by means of a wire attached at the end towards the breech of the gun, it makes and breaks the connexion with the several helices in succession, and acquires such velocity from the action of the four helices*

Benningfield's electric gun from an advertisement of 1844. Although little is known of it, the claims made certainly seem ambitious.

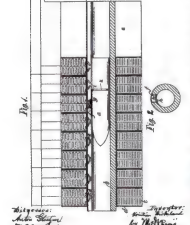
as to be projected to the distance of forty or fifty feet."

In 1901, Norwegian Kristian Birkeland is credited with having invented the coil gun. A magnetised iron projectile was pulled through a series of solenoids, with a system to disengage power to the coils as the projectile passed through them.

A later version used a coil instead of an iron projectile and a novel method of switching in which the inductance of the projectile coil was matched to the drive coils so that the back-EMF of the drive coil matched the voltage of the projectile coil so that switching would occur at zero current.

However, there seems to be a similarity with this invention and the 1845 one mentioned above.

The results were disappointing though, as a velocity of only 100 metres per second was reached with a 10kg projectile fired from a 4m long cannon; much less than the predicted 600 metres per second. Nevertheless, a projectile range of 1km was achieved. A major problem was being able to supply enough power to the device.



At left is the drawing from Kristian Birkeland's 1904 US patent entitled "Electromagnetic gun". Figure 1 shows the cross section of the barrel illustrated in an unusual downward pointing orientation and the coils in cross section. Note the projectile contained within the barrel. Full patent document at siliconchip.com.au/link/aag6 Below is Birkeland's Electromagnetic (Coil) Gun.

From the Earth to the Moon, an 1865 novel by Jules Verne, tells the story of the Baltimore Gun Club (a society of weapons enthusiasts) and their attempts to build an enormous "space gun" to launch three people in a projectile with the goal of landing on the moon. Given the date and the lack of scientific knowledge, some of Jules Verne's assumptions and calculations are surprisingly close to reality.

The above mentioned devices were based on solenoids but the rail gun we know today was invented by Frenchman Louis Octave Fauchon-Villeplee in 1916 who called it an electric cannon. Its power source was batteries.

His initial working model had a two-metre-long barrel and was intended to accelerate a 50g, 270mm projectile to 200 metres per second, for which a required current of 5000A at 40-50V was calculated.

In experiments a current of 600A was achieved which could drive a projectile through 80mm of wood at 25m, the limitation apparently being generating the large currents required. The work was abandoned after World War 1.

In 1920, Fauchon-Villeplee described a rail gun designed to propel a 100kg projectile at a muzzle velocity of 1600 metres per second, over a distance of 120km. The instantaneous power developed in the barrel would be 3.4GW at an average current of 3.55 million amps.

The gun assembly with generators was to be mounted on railway bogies and would have weighed 1000 tonnes. The power was to be produced by a homopolar generator and was designed to fire one shot every 20 minutes, consuming 60kg of petrol. The gun was not built due to lack of funding.

The June 1932 issue of "*Modern Mechanics and Inventions*" magazine mentioned two scientists whose work in generating pulsed ultra-strong magnetic fields was seen as the basis of an "electric cannon".

One was P.L. Kapitza (a Nobel Prize winner) of Cavendish Laboratory, Cambridge University and the other was T.F. Wall. It is not known where this work went in respect of a gun but a dramatic image of the hypothesised gun was produced for the magazine.

In 1933, a Texan by the name of Virgil Rigsby invented a coil gun intended to be used as a "silent machine gun" but the military had no interest in it. It was patented in 1934.

The first plans to actually use a rail gun for military service came from Joachim Hänsler in 1944, from Germany's Ordnance Office. Theory was developed and a device was built using batteries as the power source but it was never employed.

The device was able to propel a 10g mass to 1000 metres per second. This was a good speed but not much better than could be developed with chemical propellants at the time.

Further rail gun developments came from General Electric in the USA, accelerating a 45g projectile to 550 metres per second in 1957; R.L. Chapman, D.E. Harms

ELECTRIC Cannon Uses No Gunpowder

The magnetic gun, pictured on this month's cover, is foreshadowed by achievements of two English experimenters. Powerful currents working through coils around the gun barrel exert a magnetic effect on the steel shell, pulling it through the barrel at tremendous speed. Each coil has its own generator, and the shell advancing through the barrel will automatically energize the coil just ahead of it. A rotary switch could be employed to adapt the idea to machine guns.

SILENT guns sending their whistling messengers of death into the sky at speeds far beyond those now attained by powder-driven shells seem likely for the next war, using for propulsion magnetic fields so powerful that when they are short-circuited they produce miniature earthquakes.

Dr. Kapitza, F. R. S., working at the Cavendish laboratory of Cambridge University, England, in his attempts to disrupt the atom has produced magnetic fields so powerful that they "explode" the coils that produce them. This man has finally revealed the secret of the magnetic gun so long anticipated by ballistic experts. Dr. Kapitza accomplishes the electric firing of a shell by short-circuiting powerful dynamos for periods of one one-hundredth of a second.

Another English experimenter, Dr. Wall, seeking the same thing, produces ultra-magnetic fields with a more simple apparatus. Dr. Wall simply charges electrostatic condensers and permits them to discharge their powerful currents into specially made coils immersed in oil baths. Here also magnetic fields so powerful that they tear the coils to pieces have been produced. So great are these magnetic fields that they are capable of pulling iron nails out of shoes.

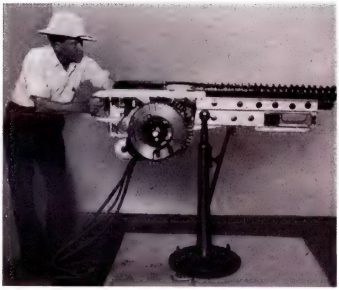
While the magnetic effects produced by both of these experimenters are of very short duration, they could be employed to impart their terrible energy to steel shells. The time limit, which cannot exceed one one-hundredth of a second, is imposed because of the powerful currents used. If these currents were permitted to flow through wire for a greater period of time, the wire would melt and temperatures greater than those existing in some of the hottest stars would be produced.

To produce a magnetic gun—a silent Big-Bertha—it will only be necessary to arrange a series of powerful coils within the gun barrel. Each coil will have its own generator and the shell advancing through the barrel will automatically energize the coil just ahead of it. By the time the shell reaches the end of the barrel it will have attained a speed far in excess of the speeds now attainable with even the highest explosives known.

Owing to the entire abse... pressures these guns may ... dinary iron or even of p... netic materials. The "magn... will be initiated by the sim... switch which will energiz... and snatch the shell from t... first leg of its journey of ...

Inventions for June

***"Modern Mechanics and Inventions"* magazine from June 1932 showing a proposed "electric cannon".**



Virgil Rigsby with what we would know as a coil gun today. It used 17 coils and a timing mechanism, similar to that used on car ignition systems at the time, was used to sequentially activate the coils. This picture is from November 1936 *Popular Science*, but there was also an earlier version that appeared in the June 1933 *Popular Mechanics*.

and G.P. Sorenson accelerating 210mg to 9.5km/s in 1963 and D.E. Brast and D.R. Sawle accelerating 30mg to 6km/s (21,600km/h!) in 1964.

The Australian contribution

In 1970, J.S. Adams, at what was then the Defence Standards Laboratory in Melbourne, accelerated a 300mg projectile to 3km/s.

The first large-scale rail gun in the world was built by John P. Barber at the Australian National University in the early 1970s and one experiment accelerated a 3g projectile to 5.9 km/s. Its power source was a homopolar generator facility designed by Sir Mark Oliphant.

The homopolar generator (see box) could deliver 500MJ of energy with current pulses of up to 1.6 million amps. A variety of rail guns were built with bore sizes from a few millimetres to 20mm, with lengths from under a metre to several metres and input currents of up to 400,000A.

The success of the Australian work led other major organisations around the world such as the US Defense Advanced Projects Agency (DARPA) to establish advanced rail gun research programs in the latter half of the 1970s.

Another Australian rail gun was at what was then known as the Materials Research Laboratory of the Department of Defence at Maribyrnong in Victoria (an institution where the Author used to work). The research program was general in scope and was about studying the science of these devices with launch velocities up to 10km/s and input energies of up to 500kJ or more.

Unfortunately, the rail gun seems to be another area in which Australia was once a world leader in a technology that was not pursued.

Advantages and disadvantages of electromagnetic launchers

Rail guns and coil guns have the advantage of greater

What is a homopolar generator?

A homopolar generator is a now uncommon type of DC electrical generator which uses a rotating disc in a perpendicular magnet field to generate a potential difference between the centre of the disc and its rim. The homopolar generator used at ANU to power the railgun had the disc in the form of a heavy flywheel that could store enormous amounts of energy which could be quickly discharged in the form of a current pulse into the railgun or other experiments it was connected to.

For details of the homopolar generator used in ANU, readers are referred to "*The Big Machine*" at siliconchip.com.au/link/aag7

The generator was in use from 1962 until 1985 after which it was dismantled. This author is privileged to have seen this device.

Mark Oliphant (in lab coat) demonstrates the homopolar generator to the Governor-General, Sir William Slim, October 1954.

Image credit: Australian National University: University Photographs, ANUA 226-895-2

Just what *is* a Rail Gun?

A rail gun comprises two parallel electrically conductive rails bridged by a conductor connected together by a moveable armature. A DC current is applied to the rails and flows through the armature and the resulting magnetic field causes acceleration of the armature, which is also either the projectile or pushes on one, down the rail and out of the device.

Often the armature has to be given a start by compressed gas, for example, as if the current is applied when it is stationary it might become welded to the rails. A plasma, which is electrically conductive, can also be used as the armature in some implementations of the rail gun.

The Lorenz force drives the armature along the rails. In any inductive loop, which is essentially what the rails and armature are, the Lorenz force acts to push the components apart via opposing magnetic fields. If one part of the inductor is free to move, in this case the armature, it will be driven along the rails in a direction determined by the polarity of the power. If the current is high enough with a fast enough rise time, it can be ejected at great velocity.

The US Navy has advanced rail guns under development although deployment seems to be considerably delayed. Two contractors are involved in development, BAE Systems and General Atomics Electromagnetic Systems (GA-EMS). The Navy's short term goal is a weapon in the 20MJ to 32MJ range that can shoot a projectile 50 to 100 nautical miles with a repetition rate of at least ten rounds per minute.

The amount of energy represented by 32MJ is the same as 4.8kg of C4 military explosive. It is also about the amount of energy behind a 10.5kg projectile with a velocity of Mach 7 (8644 km/h) although much less than that, maybe 50%, will be delivered to the target. By way of comparison, a tank's 120mm gun can generate 9MJ of energy at the muzzle and a cruise missile like the Tomahawk can deliver 3000MJ of destructive power to a target from 450kg of explosive.

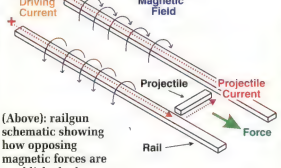
While some weapons might be more destructive with the amount of energy delivered to a target, rail gun projectiles are very fast in comparison to conventional weapons, are cheaper and can be launched in greater numbers with a fully developed operational system.

An important consideration limiting the employment of ship-mounted rail guns is the amount of electrical power required. The Zumwalt-class destroyers of the US Navy are the only non-nuclear vessels that have sufficient spare power available for a rail gun. A rail gun capable of propelling a projectile to the desired range would required 25MW of available power to charge a capacitor bank or other pulsed power system. The Zumwalt destroyer can produce 78MW while a typical naval vessel only has 9MW spare. Existing vessels would have to be fitted with extra power systems if rail guns were to be retro-fitted.

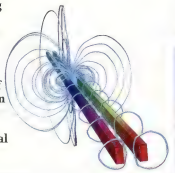
GA-EMS has three rail guns under development. The 3MJ Blitzer, the 10MJ medium range multi-mission rail gun system and the 32MJ Advanced Containment system. A live action video of the Blitzer rail gun in operation can be seen at "*Blitzer AUSA 2016*" **siliconchip.com.au/link/aah3**

In August this year (2017) it was announced that GA-EMS had completed final assembly and factory acceptance testing of a 10MJ (megajoule) medium range multi-mission rail gun system in preparation for transport to a proving ground in Utah. This weapon is a third generation design with a fifth generation pulsed power system. It is designed for a fairly small footprint on ship and mobile platforms. The system was previously tested with projectiles accelerated at 30,000g and the projectiles had two-way communication with the ground station. In the current phase of development of this rail gun there is a focus on the gun's fire repetition rate.

Another version of the rail gun is one in which a plasma (hot electrically conductive gas stripped of its outer electrons) is fired rather than a solid projectile. HyperV Technologies Corp. has developed some of these devices. The plasma rail gun is not designed to operate in air but in a vacuum or near vacuum. It is intended to be used in various types of nuclear fusion reactor projects, laboratory astrophysics experiments and in thrusters for spacecraft.

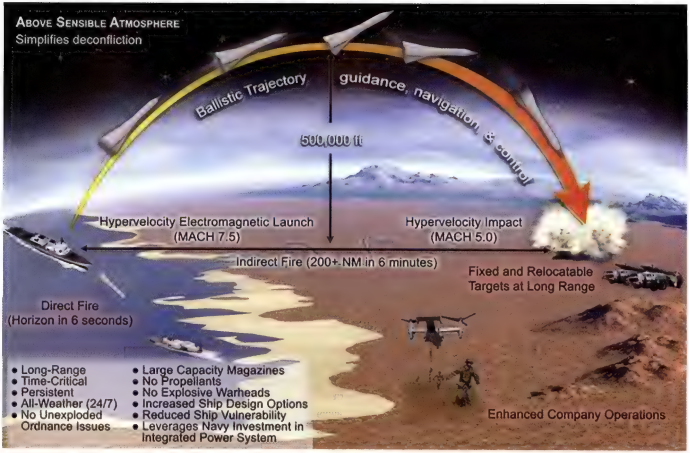


(Above): railgun schematic showing how opposing magnetic forces are established when a current flows, forcing out the projectile. You can demonstrate this effect at home as explained in the link in the text box. (Right): simulation of magnetic field lines in a railgun at a certain instant in time with the electrical potential on the rails shown as different colours.



BAE Systems prototype railgun on display on the USS Millinocket. A GA-EMS railgun was on display at the same time. Note these were on static display only and not installed on the ship and no testing has yet been done at sea, though it had been planned to do so by now.

BAE Systems 32 MJ railgun at the Naval Surface Warfare Center in Dahlgren, Virginia, USA. You can watch it in action at "*Electromagnetic Railgun - First shot at Dahlgren's new Terminal Range*" siliconchip.com.au/link/aah4.



A concept from General Atomics about how a railgun might be used as a battlefield weapon. In direct fire mode a projectile can reach the horizon in six seconds, in indirect fire mode the projectile is launched into space and can reach a land target 370km away in six minutes.

safety for their users, since no potentially hazardous propellants and explosives are needed, which simplifies the supply chain and strict storage and handling requirements. Much higher projectile velocities can also be achieved compared with conventional guns. This leads to great destructive power by kinetic energy alone although some proposed projectile designs have terminal guidance and even small explosive charges.

Another advantage of rail guns in military applications is the relatively low cost of the projectiles compared with a guided missile.

But a significant disadvantage of all launcher designs is the requirement for large generators and pulsed power supplies.

The mass driver can theoretically achieve high enough velocities for launching materials from Earth to space or from objects in space where electricity may be the only power source, eg, from solar panels and where no chemical fuels are available.

Note that by using chemical propellant guns of a very special design it is also possible to launch materials into space from Earth.

Google "Project HARP", which stands for *Super High Altitude Research Project*, [siliconchip.com.au/link/aah6].

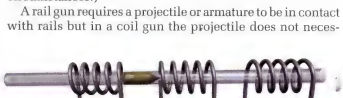
By the way, this is quite different to, and should not be confused with, the now-defunct HAARP project (*HAARP: Researching The Ionosphere*), featured in a 2012 Silicon Chip article (siliconchip.com.au/Article/492). Also see the Jules Verne Launcher [siliconchip.com.au/link/aah5].

The coil gun

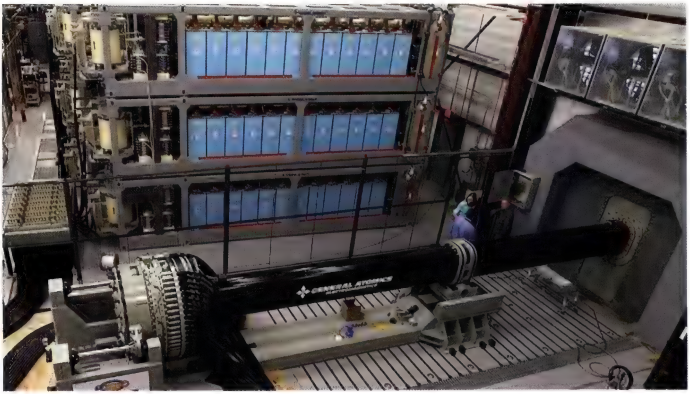
A coil gun, also known as a Gauss rifle, uses one or more coils mounted on a common axis to accelerate a projectile down the central axis of the coil assembly. It is important that when multiple coils are used that there is a proper sequential activation and deactivation of adjacent coils or the projectile will become trapped.

If one coil is used the projectile must be inserted at the proper location within the coil body. (Imagine a magnetic object put into the central axis of an electrically-energised coil, it would simply oscillate back and forth under normal circumstances.)

A rail gun requires a projectile or armature to be in contact with rails but in a coil gun the projectile does not neces-



Representation of a coil gun. The projectile has passed through the first set of coils which have been deactivated and is being pulled and accelerated toward the middle coil which has been activated. Having passed through the middle coil, which will then be deactivated, the third coil will be activated and the projectile accelerated toward that. *Diagram source: ZeroOne.*



A General Atomics Electromagnetic Systems 32MJ Advanced Containment railgun system in test configuration.

sarily need rails and can be suspended by the magnetic field, although in some designs the coils runs along a track.

Coil guns are much more simple to construct than rail guns due to fewer practical difficulties and are a popular choice among hobbyists. Some links are provided elsewhere on hobby projects.

In 1978 a Soviet scientist by the name of V.N. Bondaletov, using a coil gun, achieved a record for acceleration by accelerating a 2-gram ring to 5km/s over a distance of just 1cm.

Applications suggested for coil guns including firing projectiles into space, military mortars (one project that was funded by DARPA has projected mortars twice the range of conventional ones) and Electromagnetic Missile Launcher (EMML) for launching Tomahawk cruise missiles. These projects do not currently appear to be under active development. The Chinese are said to be developing an active protection system for tanks based on a coil gun.

The mass driver for space launch

Electromagnetic launch systems have been proposed as a cheaper method of getting materiel into space since in a conventional rocket launch most of the mass of the launch vehicle is the rocket body with relatively little payload. An electromagnetic launcher leaves the launcher device on the ground ensuring that most of the flight body is payload.

Electromagnetic launchers have been proposed to launch materials from the Earth, Moon and other bodies such as asteroids.

In the case of a launch from Earth there is a significant problem of high velocities required to launch objects into orbit of greater than 7500 metres per second. This means long launch tubes, high energies, high acceleration of 1000G or more and aerodynamic heating of the flight body.

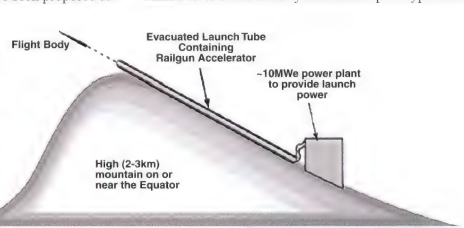
The high acceleration means that only robust payloads such as water, solid metals, fuels and other items that can easily sustain a high acceleration without damage can be utilised. Certainly, humans are out of the question for launch by this method.

The high velocity also requires some sort of cooling system and heat shield attached to the flight body.

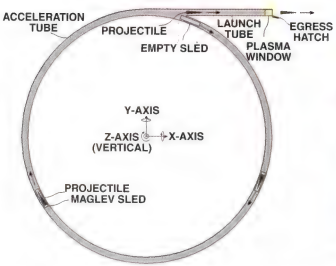
For launches from the Moon and asteroids of mined raw or refined materials the low gravity and lack of an atmosphere means that lower accelerations can be used and aerodynamic heating of the flight body is not an issue.

There have been several concepts of using a mass driver for space launch.

Mass Driver 1 was an early constructed prototype mass



A concept for an electromagnetic launcher to launch payloads into space from the side of a mountain. ***Image source, Ian R. McNab, 2003.***



Launch ring concept. This has an underground accelerator ring and an above ground launch ramp.

LaunchPoint Technologies Launch Ring. The launch tube would be built up the side of a mountain while the acceleration tube would be buried in the ground.

driver designed to launch materials from the lunar surface to the fifth Lagrange point. This is an area of stable orbit between the Earth and moon where it has been proposed to build space colonies and where objects will remain in place without station keeping.

The device was built by students at the Massachusetts Institute of Technology in 1976/77 for around $2000. It had 20 drive coils, a "bucket" (armature) in which the payload was contained and four copper tubes through which the drive current, supplied by car batteries, was carried.

The bucket was electrically connected by brushes to the rails and a microswitch was activated as the bucket passed each coil causing the energising of the appropriate coils in sequence via capacitor discharges which propelled the bucket via the Lorenz force. An acceleration of up to 33g could be achieved.

There is also a 2006 concept from LaunchPoint Technologies who developed the Launch Ring concept. This design comprises a circular evacuated ring with a linear motor and a sled containing the launch vehicle held without contact with the ring by magnetic levitation. This is accelerated around the ring multiple times until it has reached a velocity of 9000 metres per second at which point it is diverted to a ramp built up a hill or mountain which is located at a tangent to the acceleration ring.

It was estimated that the launch vehicle would reach the required velocity in about one hour. Multiple sleds could be maintained within the ring allowing multiple launches in sequence. The egress window would have a plasma window at the exit point to prevent air entering into the evacuated system.

Conceptual designs were created for both superconducting and non-superconducting systems. A later more cost effective concept was also developed but details have not been released. See **siliconchip.com.au/link/aah7**

EMALS (ElectroMagnetic Aircraft Launch System)

Traditionally, aircraft are launched from aircraft carriers using a steam catapult. These are effective and reliable but have a number of disadvantages, including uneven acceleration leading to excessive forces on air-frames and therefore higher maintenance and shorter service life; the inability to launch light aircraft such as drones and a high thermal signature and energy requirement due to the large amount of steam that has to be produced for a single launch – a typical figure is about 600kg. These systems are also very heavy and take a lot of space in the ship.

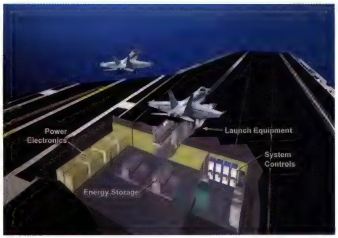
EMALS uses a linear induction motor to propel a carriage attached to the aircraft along the launch track.

Linear induction motors are also typically used on magnetic levitation trains and also the tracked train servicing the terminals at the JFK Airport in New York and are a well-established technology.

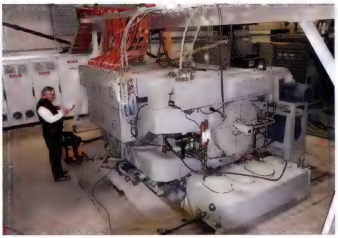
EMALS consists of six main systems comprising:

- **Prime Power Interface** that connects the ship's power to the energy storage generators;
- **Launch Motor** in the form of a linear induction motor;
- **Launch Control System** to control the current to the Launch Motor in real time;

EMALS launch motor in land-based experimental installation. *Image credit: General Atomics.*



"Below deck" view of EMALS equipment.
Image credit: General Atomics.



EMALS energy storage system in land-based testing.
Image credit: General Atomics.

- **Energy Storage System** that provides power to the Launch Motor for two to three seconds during the launch process and is recharged between launches;
- **Power Conversion System** that is a solid state system that converts power from the Energy Storage system to the appropriate voltage and current to drive the shuttle along the Launch Motor and
- **Energy Distribution System** that delivers power from the Power Conversion System to the launch motor via a system of cables and connectors.

Like other linear induction motors, EMALS use a row of stator coils along the track. These are energised only in the vicinity of the shuttle as it is propelled down the track to minimise losses. EMALS can launch a 45,000kg aircraft 91m down the length of the track to achieve a launch velocity of 240km/h.

A key to the operation of EMALS is an energy storage mechanism. Ship power is used to spin up a series of four disk (flywheel) alternators which are discharged during the launch process. A maximum energy launch will reduce the speed of the rotors from 6400 RPM to 5205 RPM.

It takes 45 seconds to recharge which is faster than a steam catapult can recharge. The maximum energy launch represents 136kWh of energy or about the same as four litres of petrol.

EMALS offers lower maintenance and staff requirements, lower life-cycle cost, reduced thermal signature, increased capabilities to launch lighter unmanned aircraft and future heavier aircraft and with reduced weight and volume. EMALS also offers flexibility of installation so can also be used on a variety of ship sizes.

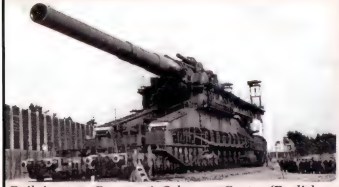
The United States Navy has an EMALS system operational on the USS Gerald R. Ford (CVN 78) and will next have one operational on the USS John F. Kennedy (CVN 79).

Associated with EMALS but a separate system is the Advanced Arresting Gear (AAG) system. This system has only just finished development after many delays but is currently installed on the USS Gerald R. Ford and will

When is a "Rail Gun" not a "*Rail Gun*"

There are various devices which have been called "Rail Guns" over the years which have nothing to do with the electromagnetic devices we are talking about here. We show two of these below.

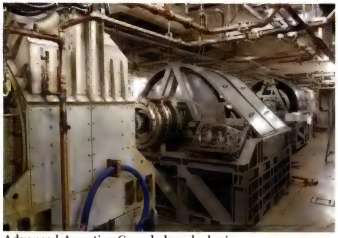
There are the railway-mounted heavy artillery pieces of both world wars. The 800mm German Schwerer Gustav (WWII) is the largest gun ever made and used in combat, and could fire seven tonne shells a distance of 47km.



Built in 1941, Germany's Schwerer Gustav (English: Heavy Gustaf) rail-mounted monster. See siliconchip.com.au/link/aah9

Another type of "rail gun" which you may encounter uses custom-made rifles (using conventional ammunition), designed for competitive shooting where the emphasis is on ultra-high precision. See siliconchip.com.au/link/aah8.

Unlimited class railgun for competitive shooting – not to be confused with the electromagnetic variety. Image source: siliconchip.com.au/link/aaha



Advanced Arresting Gear, below deck view

be installed in other carriers of that class such as the USS John F. Kennedy. Energy is absorbed via water turbines and induction motors.

Videos to watch:

"Fighter Lands on Next Generation Carrier USS Gerald R. Ford for the First Time" **siliconchip.com.au/link/aahg** and *"USNI News Video: Sailors Describe First Fighter Landing, Launch on USS Gerald R. Ford"* **siliconchip.com.au/link/aahf**

The US Department of Defense has also given the Indian Navy approval to purchase EMALS and AAG.

Resources

"The Big Machine" article about the homopolar generator built by Sir Mark Oliphant at the Australian National University which was used to power the world's first large scale rail gun: **siliconchip.com.au/link/aahb**

A very nice and clear explanation of the physics of a moving bar in a magnetic field which is relevant to the rail gun can be seen at *"Electromagnetic Induction: Induced EMF in a Moving Bar in a Magnetic Field"* **siliconchip.com.au/link/aahc**

Another video explaining the physics is *"Rail Gun example"* **siliconchip.com.au/link/aahd**

and *"U.S. Military's Most Powerful Cannon - Electromagnetic rail gun - Shoots 100 miles - Mach 7"* **siliconchip.com.au/link/aahe**

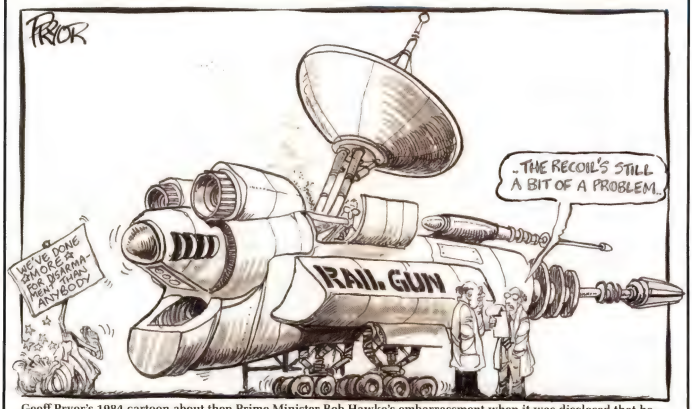
Acknowledgement: The author wishes to acknowledge the assistance of Andrew Krelle in locating some of the source documents.

The rail gun in the Australian Parliament

Rail guns have been mentioned nine times in the Federal Parliament from 1984 to 1988.

This was mainly in connection to the one that was under development by the then Defence Science and Technology Organisation's Materials Research Laboratory in Maribyrnong, Victoria and in relation to the then Government's opposition to the Strategic Defense Initiative of the United States (see below).

The questions can be seen here. **siliconchip.com.au/link/aahi**



Geoff Pryor's 1984 cartoon about then Prime Minister Bob Hawke's embarrassment when it was disclosed that he had committed Australia to collaboration on the US "Star Wars" program (Strategic Defense Initiative) through the Australian Department of Defence despite his party's opposition to it. **siliconchip.com.au/link/aahh**

Building your own electromagnetic launcher device – some ideas

Building some type of electromagnetic launcher is within the scope of an experienced and responsible electronics hobbyist and there are many plans and videos on the Internet showing how to do this.

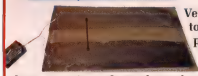
Silicon Chip presents these URLs for information only. We cannot advise you on the legality of making a high power one in your jurisdiction, particularly in Australia with its many "nanny state" laws so you would need to determine this yourself.

One tip: *never* refer to it as a "gun"– rail or otherwise!

Nevertheless, here are a few examples from overseas enthusiasts. While they do not have anything like the energy of a traditional firearm, **very high energies and voltages are involved** in devices of this kind and **they can be potentially lethal**.

A video safely demonstrating the principles of a rail gun using only cardboard, aluminium foil, glue, 9V battery, a piece of steel rod and two magnets followed by instructions on how to build a small rail gun can be viewed at *"How To Build a Railgun Experiment"* **siliconchip.com.au/link/aahj**

The author has additional details and other interesting projects at **siliconchip.com.au/link/aahk**

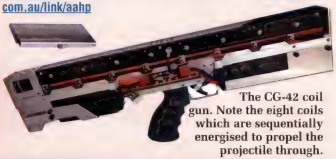


Very simple experiment to demonstrate railgun principles using basic materials of cardboard, aluminium foil, glue, 9V battery, a piece of round metal steel rod and two magnets. The magnets may not be needed if a high enough current is used.

A variation of this idea is to use model railway track as the two parallel rails as shown in the video "*Lorentz Force Experiment using N-Scale Track (240fps)*" **siliconchip.com.au/link/aahl** and a similar experiment without rail track "*Fuerzas de Lorentz (corto) / Lorentz forces (short)*" **siliconchip.com.au/link/aahm**

David Wirth and his portable railgun. It uses 3D printed components and is controlled by an Arduino. You can read more at siliconchip.com.au/link/aahn

Here is a video of a home made coil gun **siliconchip.com.au/link/aaho**. You can read more about this project at **siliconchip.com.au/link/aahp**



The CG-42 coil gun. Note the eight coils which are sequentially energised to propel the projectile through.

A DIY rail gun by Zebralemur **siliconchip.com.au/link/aahq** is claimed to be the most powerful built by an individual. It uses 56 400v, 6000μF capacitors.

Zebralemur's home made railgun, claimed to be the most powerful built by a non-government entity.

An Instructable on building your own rail gun is at **siliconchip.com.au/link/aahr** This person makes a coil gun and provides an extensive discussion about the electronics involved. *"World Fastest Six Stage Coil Gun Yak Questions Answered"* **siliconchip.com.au/l/aahs**

Thinkbotics, a company that supplies to robot experimenters have developed the EM-15 coil gun and their website **siliconchip.com.au/link/aaht** states that plans will be available "soon".

The electronics of the coil gun consist of a voltage step-up transformer converter, a Cockcroft-Walton voltage multiplier cascade, a capacitor energy storage bank, a voltage comparator to set the charge voltage on the capacitor bank, an SCR switching section and a single accelerator coil.

Construction details were published in the March 2008 edition of *Nuts and Volts* magazine, see **siliconchip.com.au/link/aahu**

Thinkbotics EM-15 coil gun.

A simple mass driver can be built with plans at this link and there is also a video of the device. **siliconchip.com.au/link/aahv**

Finally, here's a clever launcher contraption made with rare earth magnets, no power required. "*Magnet Gun -magnetic launcher*" **siliconchip.com.au/link/aahw**

SC

by Jim Rowe
(no, that's not him flying . . .)

Build this

Touchscreen Altimeter for hang-gliders, etc

With full WEATHER REPORTING on board!

This accurate altimeter has a bright colour touchscreen to display altitude in feet or metres, atmospheric pressure, temperature and relative humidity. It can show all readings at once or provide a larger display for altitude – the most important one if you're flying!

It's especially useful for hang-gliders, where the touchscreen facility is most useful.

Some ultralights, too, have a dearth of cockpit instruments – just take this one along with you when you fly! And you can use a solar panel to keep the battery charged on long flights.

Our first altimeter was featured back in 1991 and since then sensor technology has changed radically and become much, much cheaper.

Apart from being based on our popular Micromite Touchscreen, our Touchscreen Altimeter uses two tiny electronic modules which have been recently reviewed in SILICON CHIP: the Elecrow GY-68 digital barometer module (it's elsewhere in this issue) and the AM2302/DHT22 temperature and humidity module (February 2017).

Of course, even if you have no intention of leaving the Earth's surface, this project will also provide a useful weather station display with the advantage of Touchscreen control.

And if you ever decide to climb Mt Everest, this little unit can even cater for that extreme: the summit of Mt Everest is reckoned at 8848m above sea level (we go up to 9000m!) and our temperature goes all the way down to -40°C (Everest seldom goes this low during the climbing season).

Battery charge may be slightly problematical – best take a solar charger panel with you!

By the way, we are well aware that you can purchase various weather stations with colour displays very cheaply. But they don't have the touchscreen facility nor the ability to simply highlight one reading, such as temperature.

Presentation

The Altimeter is housed in two small plastic cases, one for the Touchscreen Micromite BackPack and the other for the two sensor modules. The larger UB3 case is 130 x 68 x 43mm (LxWxH) and houses the Touchscreen Micromite BackPack, together with the single 18650 lithium-ion cell which powers

Specifications

Altitude range: ..... 0-9000m (0-29520ft) above MSL or GND, with 1m resolution and ±1m accuracy
Temperature range: ..... -40°C to +80°C, with 0.1°C resolution and ±0.5°C accuracy
Relative Humidity measuring range: ..... 0 to 100%, with 1% resolution and ±2% accuracy
Barometric Air Pressure range: ..... 300-1100hPa (mBar), with 0.1hPa resolution and ±0.12hPa accuracy*
*between 950 and 1050hPa, at 25°C
Power requirements: .....230mA at 5V, (380mA at 3.7V from inbuilt 18650 Li-Ion cell)

the project and the Elecrow charger/upconverter module (reviewed in SILICON CHIP, August 2017 – www.siliconchip.com.au/Article/10754).

The smaller UB5 case measures 83 x 54 x 31mm (LxWxH) and houses the two sensor modules. The two cases are connected together via multi-way cable, which can be as short or as long as needed to suit your purpose.

So why have two cases instead of one?

We tried using a single larger case but it had problems with internal heat build-up which compromised the reading accuracy. More on this anon.

Circuit details

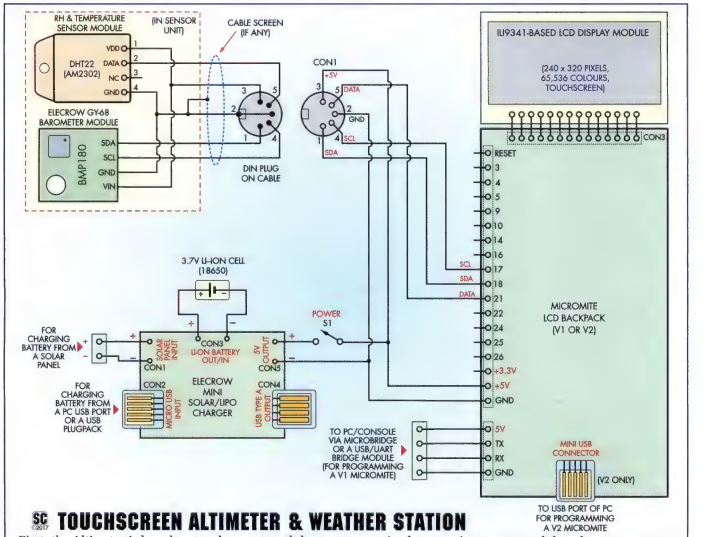
Fig.1 shows how all the modules are connected together.

Starting with the DHT22/AM2302 temperature and RH module, we won't go into its operation in great depth here since we covered this in detail in the February 2017 article (pages 46-48 – www.siliconchip.com.au/Article/10529).

The main things to know are that it has its own dedicated 8-bit microcontroller, to measure relative humidity via a special polymer capacitor and temperature via a negative temperature coefficient (NTC) thermistor.

Each time the micro uses these to take a set of measurements, it calculates the corresponding temperature and relative humidity (RH) and sends them out as a serial 40-bit data package via the DATA line.

The data is encoded using a special pulse-width-modulation system and this is decoded by the Micromite and

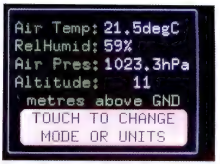


SC TOUCHSCREEN ALTIMETER & WEATHER STATION

Fig.1: the Altimeter is based on two low-cost modules, one measuring barometric pressure and the other temperature and relative humidity. Their readings are monitored by a Touchscreen Micromite BackPack which displays the data on a touchscreen readout. An 18650 cell supplies power, itself kept charged by a mini solar/USB charger.

Here's the display in Altimeter mode. The green text shows the altitude units (metres or feet) and the reference level (MSL or GND).

When you touch the button at the bottom of either of the other displays, this 'Change Settings' display appears, allowing you to make changes.



Here's the display in Weather Station mode. Again, you can touch the button at the bottom to change any of the settings or switch to Altimeter mode.

Barometric Pressure and Altitude

Basically, atmospheric pressure is due to the weight of air immediately above your location.

The primary SI unit for pressure is the Pascal (Pa), which is equivalent to a force of 1 Newton per square metre.

A column of air one square centimetre in cross section, measured from sea level to the top of the Earth's atmosphere, has a mass of about 1.03kg and a weight of 10.1325N.

This corresponds to a pressure of 101,325Pa or 1013.25hPa (hectoPascals), since 1hPa = 100Pa. So the 'standard atmosphere' is defined as 1013.25hPa.

The actual barometric pressure at any particular location depends upon its elevation, or altitude, with respect to mean sea level (MSL), because the higher the elevation, the lower the weight of air directly above you and the lower the pressure.

It also depends on various aspects of the weather, including the amount of moisture in the atmosphere – ie, the relative humidity (RH).

The relationship between air pressure and altitude is usually defined as the Barometric Formula. This can be written as:

$$\text{Altitude} = 44330 \times \left[1 - \left(\frac{P}{P_o}\right)^{\frac{1}{5.225}}\right]$$

where altitude is in metres, P is the measured air pressure and P_o is the air pressure at MSL, or 1013.25hPa. If you substitute 1013.25 for P in the above formula, the result will be 0 metres which is MSL.

displayed on the touchscreen.

Every DHT22/AM2302 module is calibrated during manufacture with its calibration coefficients saved in its micro's one-time programmable memory. These coefficients are used to achieve impressive levels of measurement resolution and accuracy.

The RH measurement range is from 0-100%, with rated resolution of 0.1% and an accuracy of ±2%, while the temperature measurement range is from -40 to +80°C with a resolution of 0.1°C and an accuracy of ±0.5°C.

The Elecrow GY-68 barometer-altimeter-temperature sensor module is based on the BMP180 device made by Bosch Sensortec, a division of the large German firm Robert Bosch GmbH. (**www.boschsensortec.com**)

The BMP180 is based on piezo-resistive MEMS technology, where MEMS stands for 'MicroElectroMechanical Systems'.

It uses a tiny sensor element which flexes mechanically in response to changes in atmospheric pressure, with the flexing sensed by measuring changes in the element's resistance.

The BMP180 chip is fitted inside a tiny 3.6 x 3.8 x 0.93mm metal package, which has a very small vent hole (about 0.5mm diameter) in the top to allow the sensor element access to the outside air.

Apart from the sensor element, there are three other functional blocks inside the device: an ADC (analog to digital converter) to make the measurements, a control unit which also provides the I^2C serial interface for communicating with an external micro, and finally an EEPROM which has 22 bytes of storage for the device's 11 x 16-bit calibration parameters.

As with the DHT22/AM2302, every BMP180 device is individually calibrated during manufacture and the calibration parameters are saved in its EEPROM.

So the external micro can read these parameters and use them to correct that sensor's readings for offset, temperature dependence and other factors.

With suitable software, the BMP180 can provide high accuracy measurements of barometric pressure, temperature and altitude above mean sea level (MSL).

The quoted relative accuracy for atmospheric pressure is ±0.12hPa (hectoPascals) from 950-1050hPa at 25°C, while the absolute accuracy is quoted as -4/+2hPa over the range from 300-1100hPa and for temperatures from 0-65°C.

All this comes from a chip which only draws about 12µA from the +5V supply!

Both sensing modules have the ability to measure air temperature. We're taking advantage of this in our Altimeter project, as the software for the Micromite takes the average of the two temperatures to achieve optimum display accuracy.

Lithium battery and charging

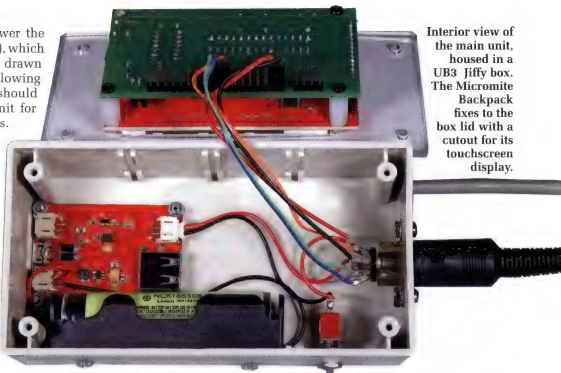
Since its main application is as an altimeter for ultra-light aircraft and hang gliders, we needed a battery power supply which was compact and light in weight, with reasonable battery life.

With those factors in mind, we settled on a single 18650 lithium-ion cell as the battery, together with one of the Elecrow Mini Li-Ion Charger/Converter modules.

A quality 18650 cell like a Panasonic, Sanyo or similar will have an energy storage capacity of between 1500 and 3400mAh (milliamp-hours) when fully charged.

So since the project draws about

230mA at 5V (mainly to power the Micromite and its backlit LCD), which translates into about 390mA drawn from the 3.7V Li-Ion cell (allowing for converter efficiency), it should be capable of running the unit for between three and eight hours.



Interior view of the main unit, housed in a UB3 Jiffy box. The Micromite Backpack fixes to the box lid with a cutout for its touchscreen display.

Watch those 18650s!

As we pointed out in a recent article, there are 18650s . . . and 18650s. Don't be tempted to use a "bargain" or unknown brand (did someone mention ebay?), especially one labelled higher than 3400mAh – they're a con, as no such 18650 cell exists yet!

Similarly, any 18650 cell you use should have protection circuitry built in – it makes the cell slightly longer but it means it won't overcharge or overdischarge.

However, we've seen cheap "protected" cells which contain no more than a spacer to make them look like they're protected.

Our tip is to always buy a reputable brand and preferably, buy here in Australia. At least then you have some recourse if the 18650 turns out to be a dud.

Charging

The Elecrow Charger module allows charging the 18650 Li-Ion cell from the USB port of a PC or a low-cost USB plugpack or alternatively, from a small solar (photovoltaic) panel.

As well, it provides a DC-DC converter to boost the 3.7V terminal voltage of the Li-Ion cell to the 5V level needed to run the Micromite BackPack and the two sensor modules. This second function only comes into operation when power switch S1 is closed.

One minor shortcoming of Elecrow's Mini charger module is that it doesn't provide any 'pass through' of the USB data lines between its USB input and output connectors (CON2 and CON4). But this only affects the initial uploading of the Weather Station/Altimeter software into the Micromite – not normal operation.

Luckily, the initial software uploading to the Micromite can be easily done, as shown in the circuit.

You will need to connect the 5V/TX/RX/GND pins of the Micromite to one of the USB ports of your PC via either a Microbridge module or a standard low cost CP2102-based USB/UART bridge module.

If you're using one of the newer V2 Micromites, it's even easier since these have a Microbridge built in. So all you need to do for uploading the software is connect the Micromite's mini USB connector directly to a USB port of your PC or laptop.

Why two cases?

Now let's turn to the physical side of the project and explain why the project is split into two small cases, instead of a single case.

We started with everything squeezed into a single UB3 case, the smallest practicable size to fit everything in.

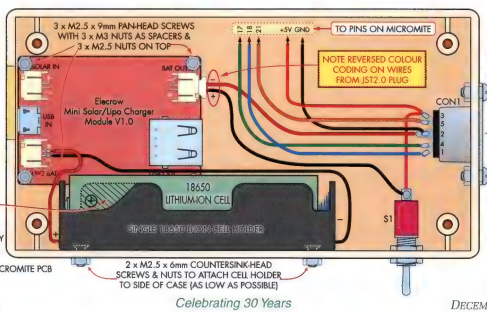


Fig.2: this wiring diagram matches the photo above but the wiring is slightly clearer. Note the reversed colour coding on the "Bat Out" terminal – black is positive and red is negative!

Weatherproofing

Because the sensor unit (especially) would normally be used in the open air (where it can read temperature and pressure) we would be inclined to weatherproof it as much as possible, consistent with still being able to make reliable readings.

To protect them, a conformal coating, such as HK Wentworth's "Electrolube HPA", could be sprayed on the underside of PCBs and also on any soldered joints. Don't spray the top side of any of the modules!

We soon discovered that the heat from the Micromite and (mainly) its LCD Touchscreen backlighting steadily raised the temperature inside the case, so that the apparent air temperature rose significantly, giving spurious readings.

So that's why we ended up with two separate cases.

As shown in the photos, the two sensor modules are mounted in the bottom of the smaller case, which has two 3mm diameter ventilation holes in the bottom of the case to ensure that conditions inside are substantially the same as those outside.

Inside the main unit, the Micromite BackPack and its Touchscreen are mounted under the case lid, while the Elecrow Mini Charger module is mounted on the bottom at the left-hand end.

The Li-Ion cell holder is mounted on the front side of the case, as low as possible so that it just clears the underside of the Micromite PCB when the lid assembly is attached.

In order to do this, the Mini Charger module is attached using only three screws, and in addition part of the cell holder's 'side flap' is cut away at the positive end.

Also mounted on the front side of the case to the right of the Li-Ion cell holder is power switch S1, a mini SPDT toggle switch.

Construction

As shown in the layout/wiring diagram of Figs. 2 and 3, assembling both units is pretty straightforward because we are just linking up prebuilt modules.

But before you can begin the assembly, you'll need to prepare both boxes by drilling and cutting the various holes. To do this, follow the diagram of Fig.4 and 5 closely.

You can avoid cutting out and drilling the holes in the UB3 box lid/front panel if you buy one of the laser-cut front panels from the SILICON CHIP online shop.

Another point to note is that before fitting any of the components into the larger UB3 case, you'll need to cut away four of the moulded splines inside the front side of the box, as shown in Fig.4. This is to allow the 18650 Li-Ion cell holder to be attached to the inside, down low enough to clear both the Mini Charger module and the underside of the Micromite LCD BackPack module.

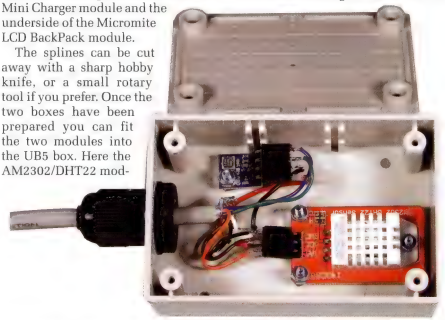
The splines can be cut away with a sharp hobby knife, or a small rotary tool if you prefer. Once the two boxes have been prepared you can fit the two modules into the UB5 box. Here the AM2302/DHT22 module is mounted inside the box at lower right, using three M2.5 x 8mm machine screws and nuts, with three extra M3 hex nuts used as spacers.

The GY-68 barometer module is mounted in the same way at upper left, in this case using a single M2.5 x 8mm machine screw and nut, with a single M3 nut again used as a spacer.

The cord grip gland can also be fitted in the 12.5mm hole at the left-hand end – but don't tighten up the outer cord gripping nut at this stage (only when you have fed the cable through it).

Next cut off two sections of SIL header socket strip: one four clips long, and the other three clips long. After removing any burrs these are slipped over the 4-pin header on the barometer module and the 3-pin header on the AM2303 RH sensor module, ready for soldering the various wires from the connecting cable.

To prepare the cable itself, carefully remove about 50mm of the outer plastic sleeve from one end. Then peel back the metal screening foil and twist it to-



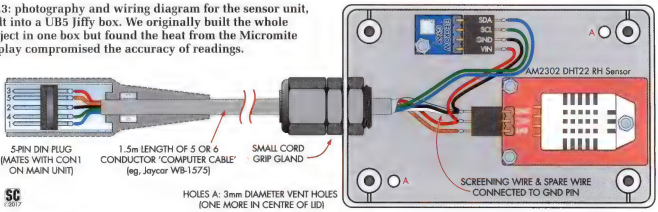


Fig.3: photography and wiring diagram for the sensor unit, built into a UB5 Jiffy box. We originally built the whole project in one box but found the heat from the Micromite display compromised the accuracy of readings.

gether with the bare wire just inside it.

Strip away about 4-5mm of insulation from the ends of the main conductors. After these ends are tinned, all of the wires together with the screening foil and wire can be passed through the cable grip gland, until the end of the cable's outer sleeve is about 5mm past the inner end of the gland. Then the gland's outer nut can be tightened up to hold the cable in this position.

Then solder the various wires to their correct pins of the header sockets on the two modules. We suggest that you use the colour coding shown in Fig.3, to help avoid swapped connections.

Two small points to note: if the cable supplied has six wires instead of five, connect the 'extra' white wire to the same socket lugs as the black ground wire and the screening foil wire.

Also note that the red wire of the cable must connect to the VIN socket lug for the GY-68 module as well as the VCC lug for the AM2302 module, while the black wire must connect to the GND lugs for both modules. This will involve two short lengths (about 40mm) of insulated wire, ideally with red and black insulation respectively.

The internal wiring of the UB5 sensor unit should now be complete and you can fit the box lid. All that will then remain is to fit the 5-pin DIN plug to the other end of the cable.

To do this, first slip the plug's outer plastic sleeve over the end of the cable and out of the way. Then carefully remove about 15mm of the cable's outer sleeve from the end, and as before peel back the screening foil and twist it together with the bare earthing wire. Then strip away about 5mm of the insulation from each of the inner wires.

Next, twist the ends of the black and white wires together, and lightly tin the ends of all bared wires before soldering them to the rear of each of the plug's pins.

As shown in Fig.3, the blue wire solders to pin 1, the green wire to pin 4, the black/white/screen wires all to pin 2, the orange wire to pin 5 and the red wire to pin 3.

When you're happy with these connections, squeeze together the cable grip lugs on the rear of the lower part of the plug shell using a pair of pliers, so that they will hold the cable in position.

Then fit the upper half of the shell and slide the plug's outer plastic sleeve back up the cable and over the plug's metal shell, to hold it all together.

Main unit assembly

Most of the information you'll need to assemble everything in the UB3 main unit box can be found in the diagrams of Fig.2, along with the internal photo. The easiest way to do this is in the following order:

First, fit the 5-pin DIN socket to the right-hand end of the box using a pair of 6mm long M2.5 screws and nuts. Then mount power switch S1 in the 6mm hole in the front side of the box, as shown in Fig.2. Next, mount the Elecrow Mini Solar/LiPo Charger module in the bottom of the left-hand end of the box, using three 9mm long M2.5 screws and nuts, together with three M3 nuts as spacers. The module should be mounted with the USB micro input socket end to the left, just inside the stepped access hole.

Slide the Li-Ion cell holder down inside the front of the box as far as it will go, orientated as shown in Fig.2.

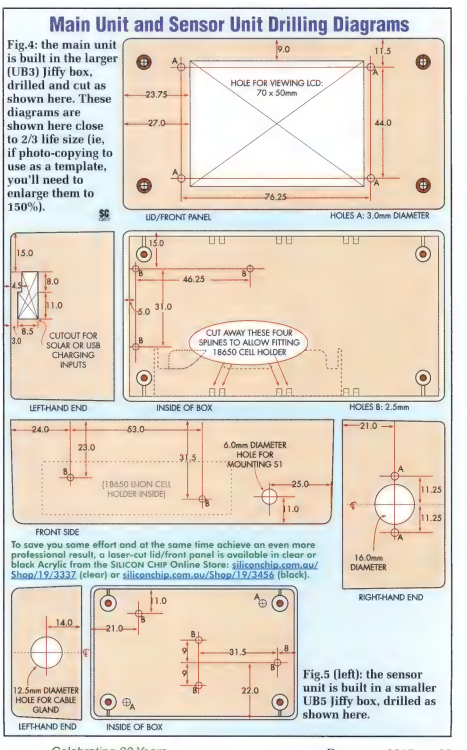


Fig.4: the main unit is built in the larger (UB3) Jiffy box, drilled and cut as shown here. These diagrams are shown here close to 2/3 life size (ie, if photo-copying to use as a template, you'll need to enlarge them to 150%).

To save you some effort and at the same time achieve an even more professional result, a laser-cut lid/front panel is available in clear or black Acrylic from the SILICON CHIP Online Store: siliconchip.com.au/Shop/19/3337 (clear) or siliconchip.com.au/Shop/19/3456 (black).

Fig.5 (left): the sensor unit is built in a smaller UB5 Jiffy box, drilled as shown here.

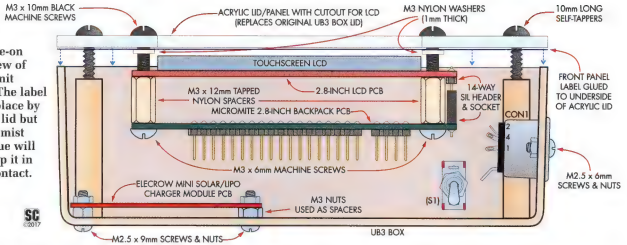


Fig.6: a side-on "X-ray" view of the main unit assembly. The label is held in place by the acrylic lid but a very fine mist of spray glue will help to keep it in intimate contact.

This should allow you to mark the location of the two holes which need to be drilled in the bottom of the holder, to match the holes already drilled in the box. You should be able to mark the hole locations using a small scriber or needle.

Then remove the cell holder again, so that you can easily drill a 2.5mm hole in each of the two marked positions. After drilling remove any burrs with a larger drill or countersink, and if you can manage it also countersink both holes on the inside of the holder. If you slide the prepared holder back down into the box, you should then be able to fasten it in position using two 6mm long countersink-head M2.5 screws and nuts – with the nuts on the outside as indicated in Fig.2.

When the holder is in place, you need to use a sharp knife or rotary tool to cut away a section of the left-hand upper 'wing' of the holder, as indicated by the cross-hatched area in Fig.2. This is to prevent it from interfering with some solder joints on the underside of the Micromite BackPack PCB, on the latter's front left. You can also see this in the internal photo.

Solder the ends of the Li-Ion cell holder's leads to the rear lugs of the JST2.0 socket on the Charger module, after cutting each one to an appropriate length and stripping and tinning about 4mm from the end of each wire. The red wire should be soldered to the lug marked '+', and the black wire to the lug marked '-'.

Next connect the two wires from the JST2.0 plug lead connected to the socket on the Charger module labelled 'BAT OUT', to their designated locations. Note that since many of these plug leads have reversed colour coding, the black positive wire should be connected to the uppermost lug of S1 while the red negative wire connects to pin 2 of CON1.

All that remains is to add the rest of the wiring, using Fig.2 and the internal photo as a guide.

Note that the three wires from CON1 which are marked as connecting to pins 17, 18 and 21 of the Micromite should be soldered at their upper ends to the lugs of a 3-way section of SIL socket strip, while the wires marked +5V and GND should be soldered to a 2-way section of the same socket strip. Both sections of socket strip will then be ready to connect to the corresponding pins of the Micromite.

The next step is to mount the Micromite BackPack and its LCD touchscreen to the underside of the box lid, or to the replacement laser-cut acrylic lid/panel if you are using this. Just before you do this, however, you may want to attach the front panel artwork shown in Fig.7 to the lid/panel, to make it look more professional.

For more information on assembling and using the TouchScreen Micromite BackPack, refer to the article in the May 2017 issue (**www.siliconchip.com.au/Article/10652**).

You can see how the BackPack and LCD is attached to the rear of the lid/front panel in Fig.6.

The LCD board is attached directly to the panel using four 10mm long M3 machine screws, with 1mm thick Nylon flat washers as spacers and four M3 x 12mm long tapped Nylon spacers underneath as 'long nuts'. Then the Micromite BackPack PCB is attached to the lower ends of the tapped Nylon spacers, using only three 6mm long M3 machine screws.

No screw is used in the front left position, because if

Parts List – Touchscreen Altimeter & Weather Station

1 UB3 jiffy box (130 x 68 x 44mm)
1 laser-cut Acrylic front panel to suit above #
1 front panel label to suit ^
1 UB5 jiffy box (83 x 54 x 31mm)
1 Micromite V2 LCD BackPack + 2.8-inch LCD #
1 Elecrow GY-68 barometer/altimeter module #
1 DHT22/AM2302 temperature/RH module #
1 Elecrow mini LiPo/Li-Ion charger module #
1 18650 rechargeable Li-Ion cell
1 1 x 18650 Li-Ion cell holder
1 SPDT mini toggle switch
1 5-pin DIN socket, panel mounting
1 5-pin DIN plug, inline type
1 1.5m length of 5/6-way screened 'computer' cable
1 3-6.5mm cable gland
7 M2.5 x 8mm pan head machine screws & nuts
7 M3 hex nuts
2 M2.5 x 6mm pan head screws and nuts
5 M3 x 6mm pan head machine screws
1 16-way female header (to cut into 1 x 4-way, 2 x 3-way and 1 x 2-way)
4 M3 x 10mm long machine screws
4 M3 Nylon flat washers
4 12mm long M3 tapped Nylon spacers
2 M2.5 x 6mm countersink head screws and nuts
1 120mm length of rainbow ribbon cable (to make interconnections)

Available from the Silicon Chip Online Shop: **siliconchip.com.au/Shop**
^ Download from **siliconchip.com.au/Shop/11/4482**

End-on views of the main unit (left photo) showing the connections for power in, from either a solar panel or a USB supply/PC port; and (right photo) the 5-pin DIN socket which connects to the sensor unit.

fitted the head of this screw would conflict with the top of the Li-Ion cell holder during final assembly.

Note that all connections between the Micromite BackPack PCB and the LCD board above it are made via a 14-way SIL header and socket at their right-hand ends.

Once the Micromite and LCD boards are secured to the underside of the front panel, you're almost ready for final assembly of the main unit.

Only two things remain to be done: slipping the 18650 Li-Ion cell into its holder (making sure that its positive end is to the left) and then fitting the 3-way and 2-way SIL sockets on the wires from the 5-way DIN socket to the correct pins along the rear of the Micromite PCB.

Plug the cable from the sensor unit into CON1, so the two units are linked together.

Programming the firmware

Your Altimeter is now virtually complete but you need to download the project's firmware program from the SILICON CHIP website, and then upload it to the Micromite.

The firmware for this project is called "Altimeter.bas", and you can download it (free to subscribers) from **www.siliconchip.com.au**.

The next step is to connect the Micromite in your Altimeter/Weather Station to a USB port of your PC, either directly in the case of a Micromite V2 or via a USB/UART bridge module in the case of a Micromite V1.

Either way, we suggest that you start up Control Panel>Device Manager to make sure that the Micromite has been recognised as a virtual COM port and to take note of the COM port number and baud rate it has been allocated.

Now you should be able to start up the MMEdit program and use it to open the downloaded Altimeter.bas program.

Then after making sure that MMEdit can communicate with the Micromite in the Altimeter/WeatherStation, it's just a matter of getting it to upload the program and then set it running.

Since the programming connection to the PC also provides power, you should find that the Altimeter/WeatherStation springs to life as soon as the program is set running.

You should see the display on the LCD showing the altitude, air temperature, the relative humidity, the barometric air pressure (see photo of the Weather Station display).

If all is well so far, the programming cable can be disconnected from the Micromite.

The display will probably go dark again, unless your have turned on power switch S1 and your Li-Ion cell has some initial charge.

Now the front panel assembly can be gently lowered into the box and the four small 10mm long self tappers used to fasten the two together.

Your Altimeter/Mini Weather Sta-

The three mounting screws for the Elecrow Charger PCB and the 5-pin DIN socket on the end. The 18650 cell holder mounts on the side wall of the case (see nuts).

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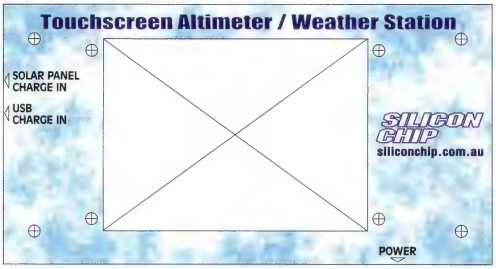

Fig.7: a full-size front panel artwork for the Altimeter/Weather Station, ready to photocopy (or download from siliconchip.com.au/Shop/11/4482). We printed ours on heavy, glossy photographic paper. The idea is that this label is mounted behind, and visible through, the clear acrylic laser-cut front panel, so it is fully protected from, especially, the weather (and grubby fingers!). This label will normally be held in place by the front panel; however, a very fine dusting of spray adhesive will hold it in position while you drill the label holes (all 3mm) and cut out the Touchscreen Display rectangle with a very sharp hobby knife.

tion should now be complete and ready to go. Charge the Li-Ion cell for a few hours (via a USB cable, power supply or solar panel) before you turn on S1 again to put the project to work.

What it can do

When you turn it on for the first time, you should get the weather station display shown in the photos.

The device will initially start up in this mode, and will also have its altitude reference set to MSL (mean sea level) and the altitude units set to metres – as indicated in the line of text just below the Altitude reading.

At the bottom of the display you'll see a red button labelled "TOUCH TO CHANGE MODE OR UNITS".

And if you do touch this button, the display will change into a one giving you the options of changing to the alternative Altimeter display, changing the altitude units to feet instead of metres (or back again), or changing the altitude reference level from MSL to the current ground level (or back again). There's also an "EXIT WITHOUT ANY CHANGES" button at the bottom of this screen.

So if you want to change over to Altimeter mode, this is done quite simply by touching the button at upper right, labelled "ALTIMETER MODE".

This will change the display over to one showing just the altitude, in large digits for high visibility. But the altimeter units and reference level won't have changed at this stage, so the text just below the altitude digits will still read 'metres above MSL'.

If you're happy with these settings, fine. But if you'd rather have the altitude in feet rather than metres, simply touch the button at the bottom of the screen to bring up the 'change options' display again.

Then touch the button labelled "FEET", and you'll return to the Altimeter screen with the reading shown in feet rather than metres.

Here's an important point to note, though. If the altitude reference level is still set to MSL, you may be getting a negative altitude reading if the air pressure in your vicinity happens to be significantly higher than the nominal MSL level of 1013.25hPa (hectoPascals).

This can be a bit confusing, but the problem is easily fixed by touching the button at the bottom of the screen once again, and then touching the "GROUND REFERENCE" button at lower right on the 'change settings' display.

This will set the altitude reference level to the current barometric pressure level; ie, the altitude at your current position.

This 'ground reference level' can be reset at any time, simply by switching to the 'change settings' display and touching the "GROUND REFERENCE" button again.

By the way whenever you change any of the settings in the 'change settings' display, all of the setting parameters are saved in the Micromite's non-volatile memory.

This means that if you turn off the device power, next time you power it up again the same settings will be restored.

You can always change back from Altimeter mode to Weather Station mode, simply by touching the button at the bottom of the screen and then the "WEATHER STN MODE" button at upper left.

Similarly, you can change the altimeter units to metres and the altimeter reference level back to MSL.

One last point: as mentioned earlier, when fully charged, a single 18650 Li-Ion cell of decent quality should be able to power the Altimeter/Weather Station for between 3.8 and 8.75 hours.

This should be long enough for most purposes, but don't forget to charge it up before going on a flight or journey.

When the cell's voltage is falling to the point where it's no longer capable of powering the unit, you'll notice that the display starts flickering.

Time to turn it off and charge it! SC

So what is the Micromite – and what will it do for YOU?

We've made many references to the "Micromite" and the "Micromite BackPack" in this article – after all, that is the platform on which the Altimeter/Weather Station is based.

The Micromite was developed in Australia by Geoff Graham and has been used extensively in SILICON CHIP projects and as a microcontroller platform in its own right.

It's similar in some respects to other microcontrollers such as the Arduino, Raspberry Pi etc. The Micromite has developed an enormous following around the world, mainly due to its ease-of-use and the fact that it uses "MMBASIC" – a variant of the hugely popular and very easy to understand BASIC language.

In past issues, we have prepared several features on the Micromite and its peripherals, including some aimed at first-time users.

Log on to siliconchip.com.au, search for "Micromite" – and enjoy!

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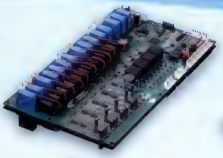

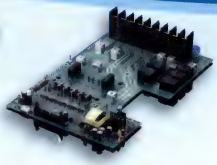

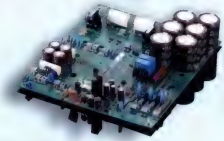

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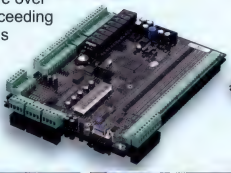

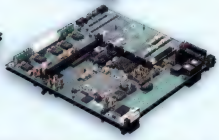

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for Beginners

by Andrew Pullin

While the Raspberry Pi (RPi) micro computer is very popular and has a very large user base, not too many people are aware that the RPi's GPIO interface can be used for some very interesting applications, such as driving fancy graphics displays. As well, it can provide a user-configurable clock and can interface easily with third party sensors and other equipment. Finding out how to do this stuff is tricky though and this article will reveal how to go about it.

The Raspberry Pi was originally developed by the Raspberry Pi Foundation, a UK Charity, to promote the teaching of basic Computer Science in Developing Countries (see siliconchip.com.au/link/aagc).

But the popularity of the cheap, single-board computer (SBC) has seen it explode onto the world market and its uses are much wider than originally intended, including as a powerful embedded controller.

The GPIO pins

The General Purpose Input Output (GPIO) connector of the RPi is typically a 40-pin header on the board but there is a little bit more to it than that. Some of the pins connect directly to the central Broadcom BCM28xx System on a Chip (SOC) IC. Some provide power supply rails and some ground connections.

These pins are unfortunately not connected in an easy-to-remember way. This is partly due to the fact that the slightly different Broadcom SOCs used in the various Raspberry Pis have different interface circuitry.

This causes some compatibility issues between earlier and later versions of the RPi.

The Raspberry Pi 1 Models A+ and B+, Pi 2 Model B, Pi 3 Model B and Pi Zero/Zero W have a 40-pin GPIO header labelled J8. The original Raspberry Pi 1 Models A and B have a 26-pin connector instead, with 14 connections missing.

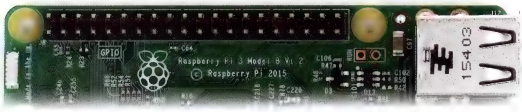
To make things even more confusing, the Model B rev. 2 also has an extra 8-pin header labelled P5 on the board (and for some reason, P6 on the schematics) offering access to an additional four GPIOs.

Another point of difference is that Models A and B provide access to the ACT status LED via GPIO pin 16 while Models A+ and B+ provide the same access via GPIO 47 as well as the power status LED via GPIO 35.

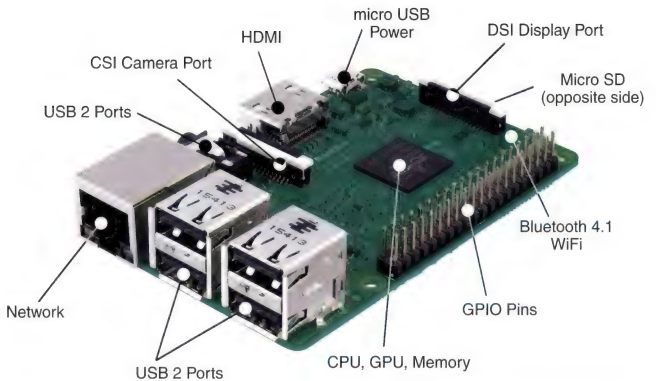
GPIO pin assignments

For the moment though, let's look at the 26/40-pin main GPIO header. Fig.1 shows the pins on this header, numbered according to their position and colour-coded based on their function.

The accompanying legend indicates the meanings of these colours. Unfortunately, this is not how the pins are



Enlarged for clarity, this shows not only the GPIO header (the double row of pins along the top, labelled J8 on the PCB) but also the identification of this particular RPi (a Raspberry Pi 3 Model B V1.2).



An enlarged version of the Raspberry Pi 3, identifying the various interfaces. The one we are particularly interested in is the row of 40 header pins (2 x 20) along the edge of the board, labelled GPIO (General Purpose Input Output) Pins. This article gives a broad range of uses for the GPIO which you otherwise might not have been aware of.

actually mapped to the RPi processor.

This is shown in Fig.2 – ignore the shading for now and just compare the pin numbering to Fig.1. As you can see, it is quite different. The numbering scheme in Fig.2 shows the RPi I/O pin number that's connected to each pin on the header (referred to below as the BCM pin number, which is short for Broadcom).

This may seem a little confusing but in many cases, you can simply connect whatever digital input/output that you need to control to any one of these pins and then change your software to communicate using the number shown in Fig.2.

The good news is that this numbering scheme applies to any RPi with a 40-pin GPIO header.

There are some cases where you need to use a specific pin for a specific purpose, though. This is indicated by the extra labels in Fig.2 and the shading around the outside of the pins, which shows how the pins are related in terms of function.

The special functions include one UART, two SPI buses, two I²C buses, three PWM outputs and three square wave outputs.

Fig.1: the pins on the GPIO header, numbered according to their position and colour-coded based on their function.

In case you aren't familiar with the acronyms:

UART stands for Universal Asynchronous Receiver/Transmitter and is basically a 3.3V bidirectional RS-232 serial port.

SPI is Serial Peripheral Interface, a higher speed (and simpler) bidirectional serial bus.

I²C stands for Inter-Integrated Circuit and is a slower serial bus which only requires two wires (plus ground) and it can be shared by multiple devices, unlike SPI or VART.

PWM stands for Pulse Width Modulation and allows you to produce a square wave with a variable frequency and duty cycle, eg, to control the brightness of LEDs, motor speed and so on. The square wave/clock outputs are similar except that only their frequency can be varied; the nominal duty cycle for these outputs is 50%.

These functions are shared with the general purpose I/O pins, meaning the pins labelled with special functions can be switched between normal inputs, normal outputs or those dedicated functions. So if you want to use one of

Fig.2: the RPi I/O pin number that's connected to each pin on the header (referred to in the text as the BCM pin number, which is short for Broadcom).

NOTE: URL "SHORTLINKS"

URLs (website addresses etc) in this feature have been shortened to Silicon Chip Shortlinks, saving you a lot of keystrokes (and mistakes!). In the online version, clicking on these shortlinks will take you direct to the relevant website.

these functions, you will have to use a pin or set of pins as indicated in this diagram.

Before we move on, here's a hint: before hooking any hardware up to the GPIO port, first figure out which of these dedicated-purpose pins you need to use. You can then use the remaining pins for other digital I/O tasks without any conflicts.

Serial bus connections

UART connections are simple; TXD is the transmit pin and RXD is the receive pin. You could arrange for two Raspberry Pis to communicate with each other by connecting TXD on one to RXD on the other and vice versa, then making a ground connection between the two.

The I^2C buses also have two pins but they have different purposes. SDA (SD) is the data pin and SCL (SC) is the clock pin. All devices on an I^2C bus have their SDA pins joined together and their SCL pins joined together. On each bus, there should be a single pull-up resistor between each of these two networks and the 3.3V supply rail. The values of these resistors depends on the bus speed.

For more information, see **siliconchip.com.au/link/aagd**

SPI buses have at least three pins. SCLK is the clock and this is wired directly between the master and each slave device on the bus. MOSI stands for "master out, slave in" and MISO "master in, slave out". Like SCLK, all identical pins on the bus are joined together.

SPI bus zero has two additional chip enable/slave select (CE) pins which can be wired to two separate slaves and these are pulled low to indicate which slave the master is communicating with at any given time.

You can have more than two slaves on the SPI0 bus but then you will need to use additional GPIO pins, set as outputs (normally high) and pull them low manually before initiating communication with that slave (and bring it high when finished).

The SPI1 bus has three hardware CE pins, so you can have one more slave than on SPI0 before you need to resort to manually driving the chip enable/slave select pins. We have more details on using these serial buses below but first let's look at the other functions available on the GPIO header.

Power supply rails

You can use some of the pins on the GPIO header to power external circuitry. Pin 2 and 4 are both connected to the 5V rail, which is normally directly connected to the RPi's power supply (typically a USB charger). Pins 1 and 17 provide a regulated 3.3V supply while pins 6, 9, 14, 20, 25, 30, 34 and 39 are ground connections.

These eight ground pins are all joined together by the ground plane on the RPi so it doesn't really matter which one(s) you use for connecting either power supplies or as a ground reference (eg, as part of a voltage divider).

However, you probably shouldn't use the same ground pin for both purposes. So use at least one dedicated ground reference pin, while the others can be used as a supply rail.

In practice, when powering circuitry from one of the 3.3V or 5V pins, use the nearest ground pin to complete the circuit.

Remaining GPIO pins

All pins, other than the power and ground pins, can be used as either inputs or outputs. This is configured by the software running on the Raspberry Pi. Pins that are not labelled with special functions in Fig.2 can only be used in this manner while the other (special function) pins can be used as inputs or outputs only if they are not being used for their specific function.

You need to be wary when using the GPIO pins as inputs since most of them have pull-ups or pull-downs built into the Raspberry Pi. Referring to the pin numbers given in Fig.2, those labelled 0-8 are pulled high by default while the rest are pulled low. Note that the pins which are pulled high include all four I^2C pins plus both SPI-0 Chip Enable pins, which makes sense when you consider their functions.

GPIOs which are configured as outputs can drive the digital inputs of other ICs or light LEDs if the current is limited to what the Broadcom chip can handle (16mA each, 51mA total). But they are not designed to drive anything directly that requires high current like motors. Output current can be boosted in various ways, such as by adding transistors or using a third-party HAT (Hardware Attached on Top) board which boosts the current capabilities.

Note also that any GPIOs which are driven externally must not be driven below 0V or above 3.3V. This can damage the RPi. For signals which may exceed these limits, you need to use either a series resistor and clamping diodes or a level-shifter IC.

None of the RPi pins are 5V-tolerant.

If you need to communicate with a digital chip that uses 5V signalling, in many cases, a 3.3V output from the RPi will successfully drive the input of the 5V device.

But you'd better check the device's data sheet to make sure that it will reliably read voltages above 3V as a high level. For signals going from the 5V device to the RPi, you're best off using a level shifter IC such as the 40109B although there are other approaches.

For pins which are programmed as digital inputs, the software can read their value and this will return a value of zero (when the voltage on that pin is low) or one (where it's at or near 3.3V). Similarly, for pins set as digital outputs, the software can set their value to zero, in which case the voltage will be pulled down to around 0V, or one, in which case the pin's voltage will be pulled high, close to 3.3V.

So that covers the basics of RPi GPIO and you can find tutorials on the internet which show you how to program the I/O pins as digital inputs or outputs. But the devil is in the detail and those details are what makes the RPi really useful.

Alternative pin functions

The Raspberry Pi Organisation website (**siliconchip.com.au/link/aagc**) has some very useful information on it about everything Pi but it is sometimes hard to find the more technical information unless you know where and what to look for.

Often, it is simpler to just Google for information elsewhere to find it, then search the Pi site separately. Having done the above, I discovered a very useful website at

siliconchip.com.au/link/aage

This website provides all the pinouts of the GPIO on the Raspberry Pi and here is where the first surprise comes from.

A hidden graphics display function

The GPIO header can do more than one thing if you know how and where to look for the information. The first thing I learned was that the GPIO can be used as an up to 24-bit colour display driver called the Parallel Display Interface (DPI). The details for the DPI can be found at: siliconchip.com.au/link/aagf. In a nutshell, this interface can be used to drive an RGB display using one of three formats;

- RGB24 (8-bit red, 8-bit green and 8-bit blue),
- RGB666 (6-bit red, 6-bit green and 6-bit blue) or
- RGB565 (5-bit red, 6-bit green and 5-bit blue).

The DPI is controlled by the Graphics Processing Unit (GPU) part of the Broadcom SOC and is user configurable via a simple text file in the Linux Operating System that's typically used on the RPi.

User-configurable clocks

There are three user-configurable General Purpose Clock (GCLK) pins on the GPIO header. These signals are derived from the peripheral clock sources via clock generators with MASH (multi-stage noise shaping) dividers. These allow the GPIO clocks to produce audio signals.

Wow! That was unexpected. I can see the need and use for some kind of clock interface on the GPIO interface but to have the capability to drive audio devices out of the box is pretty powerful.

As shown in Fig.2, the Clock Pins on the GPIO header are:

- Pin 7 (BCM 4): GCLK0
- Pin 29 (BCM 5): GCLK1
- Pin 31 (BCM 6): GCLK2

Dallas 1-wire protocol (w1)

This one is pretty technical and very confusing for beginners, especially since it lies and actually needs two wires (one for data and one for ground). Basically, this is used in a very simple master/slave configuration to communicate with certain devices such as the DS18B20 digital temperature sensor.

The default pin used for this protocol is pin 7 on the GPIO header (BCM 4) but this can be changed. If you are interested in doing this, refer to our article titled "*1-Wire Digital Temperature Sensor for the Raspberry Pi*" in the March 2016 issue (siliconchip.com.au/Article/9849) which has all the details.

Pulse Code Modulation (PCM)

PCM is a digital representation of a sampled analog signal. The Raspberry Pi can produce this form of digital audio output which can be fed to a Digital to Analog Converter (DAC) for high quality sound. The output signal from a DAC chip is normally a couple of volts but with only a weak drive strength so it will probably need to be fed to an audio amplifier before it can power headphones or speakers.

You can also use this PCM interface to connect to a high-speed ADC (analog-to-digital converter), ie, the opposite of a DAC. Or you can even use it with a CODEC, which is basically a synchronised DAC and ADC in one package.

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The PCM function is available on the following four pins:

- Pin 12 (BCM 18): PCM CLK (Clock)
- Pin 35 (BCM 19): PCM FS (Frame Synchronisation)
- Pin 38 (BCM 20): PCM DIN (Data In)
- Pin 40 (BCM 21): PCM DOUT (Data Out)

There are a number of tutorials on how to use this PCM interface on the Internet. This one from AdaFruit is useful: **siliconchip.com.au/link/aagg**

Note that CLK is the bit clock and there will be one pulse on this line for every bit transmitted to the DAC (DOUT) or received from the ADC (DIN). The FS pin will typically produce one pulse for every set of samples transmitted and/or received. In the case of a stereo DAC/ADC/CODEC, this is one pulse for every pair of samples (ie, left and right channels) and the current polarity of the FS signal indicates which channel is being transmitted/received.

Depending on the sampling rate and resolution, these signals can have quite high frequencies; up to around 24MHz. So signal routing can become an issue.

Inter-Integrated Circuit (I^2C) details

I^2C is a serial communication protocol originally developed by Philips Semiconductor to enable simple low level communication between chips and uses two wires plus ground, as described earlier. It is now a communication standard in the computing world for sensors, microcontrollers, port expanders and more.

Sensors! Microcontrollers! Now we are talking.

I^2C is supported by a large range of devices, especially devices which don't need to get a lot of data in or out; this is one reason why most sensors support I^2C. You can also use I^2C to communicate with another micro, however, this will be slower than if you use SPI (as described below).

The primary I^2C port on the RPi is I2C1 and uses the following two pins:

- Pin 3 (BCM 2): I2C1 SDA (data)
- Pin 5 (BCM 3): I2C1 SCL (clock)

As the I^2C Pins on the GPIO port have built-in pull-up resistors, you don't need to add external resistors for normal low-speed signalling. However, you may need to add extra pull-up resistors for higher speeds.

Again, there are some very good tutorials on the Internet and if you are serious about using your RPi then learning as much as you can about I^2C cannot be a bad thing. Try this one: **siliconchip.com.au/link/aagh**

There is a second I^2C port (known as I2C0) on the following pins:

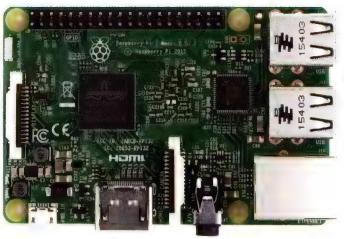
- Pin 27 (BCM 0): I2C0 SDA (EEPROM Data)
- Pin 28 (BCM 1): I2C0 SCL (EEPROM Clock)

As a beginner, I would strongly advise that you do not use I2C0. The reason for this is that it is wired up directly to the EEPROM on the RPi. An EEPROM is an Electronically Erasable Programmable Read Only Memory.

The one on the RPi can be wiped and reprogrammed using these GPIO pins and that could make your RPi less useful than a brick if you don't know what you are doing. Don't say I didn't warn you!

Serial Peripheral Interface (SPI) details

The SPI is also known as the four-wire serial bus and allows you to do some really cool things. One of the most common uses of SPI is to communicate with other devices like Arduinos, enabling you to load Sketches directly into them.



Shown here for comparison and identification, these are the front (above) and rear (opposite) views of the Raspberry Pi Model 3 micro PCBs.

As described earlier, there are two SPI buses available on the 40-pin GPIO. The first one, SPI0, uses the following pins:

- Pin 19 (BCM 10): SPI0 MOSI (Master Out, Slave In)
- Pin 21 (BCM 9): SPI0 MISO (Master In, Slave Out)
- Pin 23 (BCM 11): SPI0 SCLK (Serial Clock)
- Pin 24 (BCM 8): SPI0 CE0 (Chip Enable/Slave Select 1)
- Pin 26 (BCM 7): SPI0 CE1 (Chip Enable/Slave Select 2)

The second port, SPI1, is on:

- Pin 38 (BCM 20): SPI1 MOSI
- Pin 35 (BCM 19): SPI1 MISO
- Pin 40 (BCM 21): SPI1 SCLK
- Pin 12 (BCM 18): SPI1 CE0
- Pin 11 (BCM 17): SPI1 CE1
- Pin 36 (BCM 16): SPI1 CE2

One of the things that make the SPI peripherals so versatile is that they have several "master modes" which allow communications with different kinds of chips. The first mode is "Standard Mode" which is the normal 3-wire protocol (not including chip select or ground).

The second is "Bi-Directional Mode" which uses one less wire. MISO is not used and MOSI instead functions as MOMI (Master Out, Master In) where it functions as either MISO or MOSI depending on whether data is being transmitted or received.

The third mode is "LoSSI Mode" which stands for Low Speed Serial Interface. This is a 9-bit communications mode typically used to interface with small LCD screens.

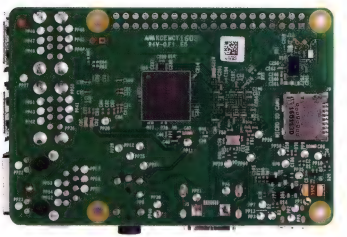
A great explanation of all these modes is available on the Raspberry Pi Foundation website here: **siliconchip.com.au/link/aagi**

UART serial port details

As we said earlier that a UART is typically used for RS-232 communications.

The U for Universal means that transmission speed and data format are configurable.

As it is an asynchronous serial port, there is no need for a



With the exception of the micro SD socket (right side of the PCB) there is virtually no connection made to the rear of the PCB.

separate clock signal and so two wires can be used for full duplex communications (simultaneously transmitting and receiving data).

This type of serial port has been used for decades to get different devices to talk to each other.

Back in the 1980s, I used to work at a Cabling Company in Adelaide and I had a book with about 100 different serial port configurations and how to wire them up. It impressed me back then and not much has changed. The pins used for UART are:

- Pin 8 (BCM 14): TX/TXD (transmit)
- Pin 10 (BCM 15): RX/RXD (receive)

Since we also need a common ground, there is a convenient one at pin 6. A good general discussion of serial communications on the RPi can be found here: **siliconchip.com.au/link/aagj**

JTAG

Most 32-bit and 64-bit microprocessors support an interface known as JTAG which stands for "Joint Test Action Group". This can be used for programming and testing various chips and the chips can be chained together so that a single JTAG interface can be used to communicate with all of them, simplifying circuit board layout.

As well as programming chips, JTAG can be used for "boundary scan", which allows a device to inspect and possibly change the state of the pins on an IC. For debugging, the JTAG interface can provide one or more "test access ports".

Note that using a JTAG interface generally requires complex and quite specialised software and while we have successfully used it to program some devices, it really is a lot of work to get up and running (and beyond the scope of this article).

If you want to know more then Google is your friend. This is a very good tutorial for debugging a Raspberry Pi using JTAG but we have to warn you that it's heavy going: **siliconchip.com.au/link/aagk**

The RPi has two possible sets of JTAG pins, with only the TRST (test reset) function fixed to BCM pin 22. The other JTAG functions are TDI (data in), TDO (data out), TCK (clock), TMS (test mode select) and RTCK (synchronisation clock). For the two possible pin assignments for each of these functions, see the link above.

Further information

The Broadcom BCM2835 SOC was used in the original RPi Model A1/1+ and Model B1/1+; the BCM2836 on the Model B2; and the BCM2837 on the Model B2v2.1 and Model B3.

All of these SOCs are backwards-compatible with the BCM2835 and a large amount of very technical and very useful information can be found in the BCM2835 ARM Peripherals Datasheet at: **siliconchip.com.au/link/aagl**

No analog inputs or outputs

There is only one sticky point about the RPi GPIO compared to other micros and this is that the "out of the box" version has no analog inputs or outputs.

This is an issue because there are a multitude of sensors available on the market and not all of them have a digital output so you can't directly connect them to the Pi. The operating word here is "directly".

The Pi can create analog signals (sort of) by using PWM and then passing this signal through a low-pass filter but that's pretty crude and only works well in certain situations. You can use the PCM interface described above with a DAC but that requires quite a few extra components.

The most common solution for analog I/O is to plug in a HAT board designed for this purpose. (HAT stands for Hardware Attached on Top).That is certainly an easy way to do it, but of course HATs cost money and so the Community has been hard at work problem solving and come up with a few ideas of its own.

While it is of limited use, you could consider combining an external comparator with the PWM or PFM functions to form a "Poor Man's ADC", as described here: **siliconchip.com.au/link/aagm**

Another common method is to use an off-the-shelf ADC module such as one with the MCP3004/3008 and interface to it using the GPIO pins.

One of the great things about the MCP3004/3008 is that they have built-in SPI interfaces. A tutorial showing how to do this can be found at: **siliconchip.com.au/link/aago**

How to access GPIOs through software

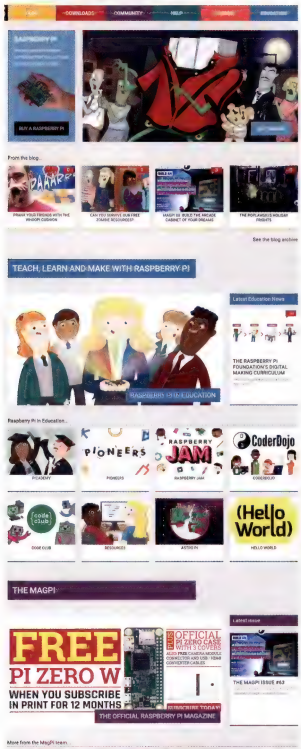
There are a few different ways to control the GPIO pins from software on the RPi. Some are supplied with the RPi operating system and some are from third parties.

The Raspberry Pi Foundation recommends running the NOOBS operating system, which is a custom-built version of Linux.

But it is not the only operating system available. There are several versions of Linux, Windows 10 IoT Core and one called RISC OS. If you're using the recommended NOOBS, you will already have most of the software libraries that you need.

The Raspberry Pi Foundation recommends using the Python programming language that comes standard with NOOBS and the C language is also very common; it too comes standard.

Each of the many tutorials I discovered had various libraries and technologies to install depending upon the application, but one such common library is WiringPi,



The RPi website, raspberrypi.org, has a wealth of information and references to help you on your way.

which can be found at siliconchip.com.au/link/aagn

According to their web page, "WiringPi is a pin- based GPIO access library written in C for the BCM2835 used in the Raspberry Pi. It's released under the GNU LGPLv3 license and is usable from C, C++ and RTB (BASIC) as well as many other languages with suitable wrappers. It's designed to be familiar to people who have used the Arduino 'wiring' system."

Beginners may find Python programming easier. We published an article in the November 2016 issue titled "*Using your Raspberry Pi with a smart-phone as WiFi-controlled switch*" (siliconchip.com.au/Article/10416).

It gave detailed set-up procedures and sample code which shows how to control some GPIO outputs from a Python web script. That code could be adapted to perform other tasks quite easily.

If you are familiar with C/C++ then we suggest that you install WiringPi and give it a go. After that, the sky is the limit.

Conclusion

While Raspberry Pi was intended as a low-cost computer for educational purposes, the GPIO port also gives users the ability interface the Pi to the real world quickly and easily.

I now have two Raspberry Pis and a couple of Arduinos and what started out as a simple search to learn a bit more about how to make them talk to the world has ended up as this article.

I hope readers can get use it as a jumping-off point for their own projects based on the Raspberry Pi.

References

- A general overview of the Raspberry Pi from Wikipedia: siliconchip.com.au/link/aagq
- Official GPIO documentation: siliconchip.com.au/link/aagr
- Comprehensive GPIO Pinout guide for the Raspberry Pi: siliconchip.com.au/link/aags
- Compute Module I/O pins: siliconchip.com.au/link/aagt
- Display Parallel Interface details: siliconchip.com.au/link/aagu
- BCM2835 ARM Peripherals Datasheet from Broadcom, 2012 (PDF): siliconchip.com.au/link/aagv
- Raspberry Pi debugging with JTAG (PDF): siliconchip.com.au/link/aagw
- Pulse Code Modulation interface: siliconchip.com.au/link/aagx
- I²C with Raspberry Pi: siliconchip.com.au/link/aagy
- SPI with Raspberry Pi:siliconchip.com.au/link/aagz
- Using UART on Raspberry Pi with Python: siliconchip.com.au/link/aah0
- GPIO Interface library for the Raspberry Pi: siliconchip.com.au/link/aah1
- MCP3004/3008 4/8-channel 10-bit ADCs data sheet (PDF): siliconchip.com.au/link/aah2

The Raspberry Pi 3 is distributed in Australia by element14. See siliconchip.com.au/link/aagp It is available through a number of retailers including Altronics and Jaycar. SC

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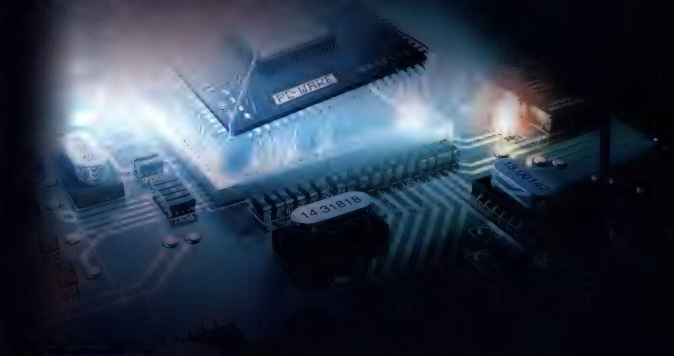

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THE ALTRONICS MEGA BOX

Make your Arduino projects easier to build and look much more professional with this kit from Altronics. It includes a pre-cut plastic instrument case, 16x2 alphanumeric LCD, four illuminated pushbuttons, two relays, an infrared receiver, rotary encoder and pluggable terminal blocks. This makes building your Arduino Uno or Mega project a breeze.

Article by Bao Smith

The Altronics Mega Box kit (Cat K9670; www.altronics.com.au/p/k9670-inventa-mega-box-for-arduino/) is a clever Arduino prototyping system developed by Altronics.

It comes with a large PCB measuring 197 x 115mm and the Arduino module and optional shield board plug into this. The PCB then neatly fits into the supplied case with the controls accessible through holes cut into the front.

It's easy to build since all the components are through-hole types. While we describe it as a prototyping system, it's quite possible to build a finished project using it; something that would come in handy everyday.

As well as the extra components mentioned above which you can use to build your project, the PCB has a 210-pin prototyping area which lets you fit the extra components you need which are not already provided by the Mega Box or fitted to the Arduino or shield boards.

All the connections from the main Arduino board and the other hardware in the box are broken out into female headers so that you can easily make connections between them using jumper wires.

The Mega Box also has a lot of extra power supply connection points, which you will often find you need. For example, near where the Arduino module is mounted, there are four sets of five sockets giving you additional 3.3V, 5V, GND and V_{IN} connections. Similarly, there are two 14-pin headers near the prototyping area, one giving you access points to the 5V rail and the other GND.

Due to the way the boards are mounted they provide a separate 6-pin in-circuit serial programming (ICSP) connector. Then you have connection points to attach wires for interfacing with other components like the illuminated pushbuttons, relays, LCD, LEDs, rotary encoder and infrared receiver.

Note that to take full advantage of all the features in the Mega Box, you really need to use an Arduino Mega to have enough I/O pins. But you certainly can use it with an Uno for some applications and this is how we tested it.

What can it be used for

When you plug a shield board into an Arduino, you can play around a bit but all you're really left with is a bit of a curiosity. To turn it into something truly useful, you need a user interface for your device, some kind of enclosure and so on. The Mega Box gives you all that.

For example, you may recall the article in our July 2017 issue on building the Arduino Music Player (See www.siliconchip.com.au/Article/10722).

We plugged an MP3 player shield into an Arduino Uno but to make it truly useful, we had to add a keypad and an LCD so you could control it. And while that worked well, all you ended up with was three separate modules connected by flying leads; hardly a "finished product".

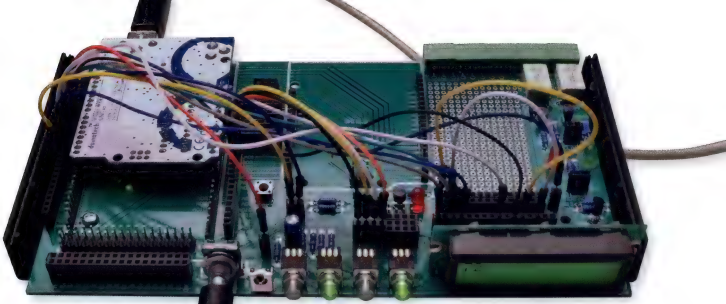
If we had the Mega Box, we could have easily built that finished product and with a lot less hassle. In fact, you could take our Arduino Music Player code and adapt it to the Mega Box, giving quite a nice little package.

It already has an LCD module onboard and since it has a remote control receiver too, you could use a universal remote to control it. That's even more convenient than the numeric keypad we used at the time.

You could also use the four illuminated pushbuttons to provide standard functions such as play, stop, pause and next/previous track, and the rotary encoder to scroll through menu items. The more we think about it, the more we realise that adapting the code in this manner would be a really fun project!

You may also remember our Arduino-based Digital Inductance and Capacitance Meter from the June 2017 issue (see www.siliconchip.com.au/Article/1067). Guess what – Altronics have actually designed a shield board for that project and it integrates perfectly with the Mega Box.

We don't have space to describe it



The Altronics Mega Box connected and running the provided example program. The illuminated pushbuttons are controlled via an IR remote control, and the LCD backlight brightness is adjusted by the rotary encoder, with an integer value displayed on the screen indicating the number of units away from the rest position of the rotary encoder.

fully in this article but we'll show how to build it and integrate it with the Mega Box (or separately) next month.

Those are just two examples of what you can do with the Mega Box. Given the plethora of Arduino shields, the hardware provided by the Mega Box itself and the ability to add extra components in the prototyping area, it's a really flexible system that would be suitable for a lot of different purposes.

Circuit description

The Mega Box circuit is shown in Fig.1. Much of this is taken up by the Arduino module, the optional shield and the wiring between them.

The headers where the shield can be plugged in are wired directly to the corresponding pins on the Arduino, which is also plugged into a set of headers. So the shield works as if it's plugged on top of the Arduino board, even though the two are mounted side-by-side.

A third set of headers, shown next to the ones the Arduino is plugged into, are provided so that it's easy to wire up any free Arduino pins to other parts of the board.

Most of the rest of the circuitry is in separate blocks with headers for the inputs and/or outputs of each block. So to use one of these sub-circuits, all you have to do is run jumper wires between the Arduino headers and the headers for that sub-circuit.

One of the few portions of circuitry already wired to the Arduino itself surrounds LED3, which lights up when the SCK pin is high, indicating that SPI serial communication is in process.

LED3 is driven by NPN transistor Q4 which is in turn driven by pin 13 (the SCK pin on the Arduino Uno) via a 10kΩ current-limiting resistor. A second 10kΩ base pull-down resistors shunts any leakage current to ground.

There's also a reset pushbutton (S5) on the Mega Box board because the button on the Arduino itself is inaccessible due to being mounted upside-down. This is simply wired between the Arduino reset pin and ground.

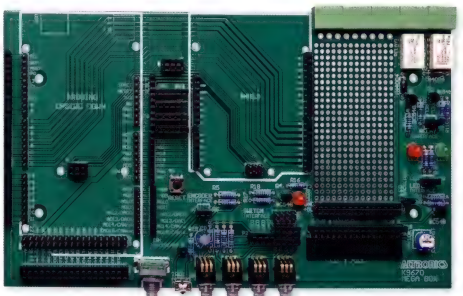
Headers CON3-CON6 provide an easy way to access the 3.3V, 5V and V_{IN} (DC input) supply rails and make ground connections. Each provides five sockets to make connections to one of these rails.

Separate sub-circuit blocks

Pushbuttons S1-S4 are illuminated momentary types; the illumination is provided by a built-in LED. Three headers are provided to make connections to these buttons.

One 8-way header (CON2) gives access to the LED anodes via 1kΩ current-limiting resistors; the cathodes are connected to ground. That same 8-way header also gives access to the switch common terminals.

Two additional four-way headers



This is what the PCB should look like after all the soldering has been completed. Three of the 3-way screw terminals do not have a matching relay, so you will need to solder wires to the adjacent pins to utilise them.

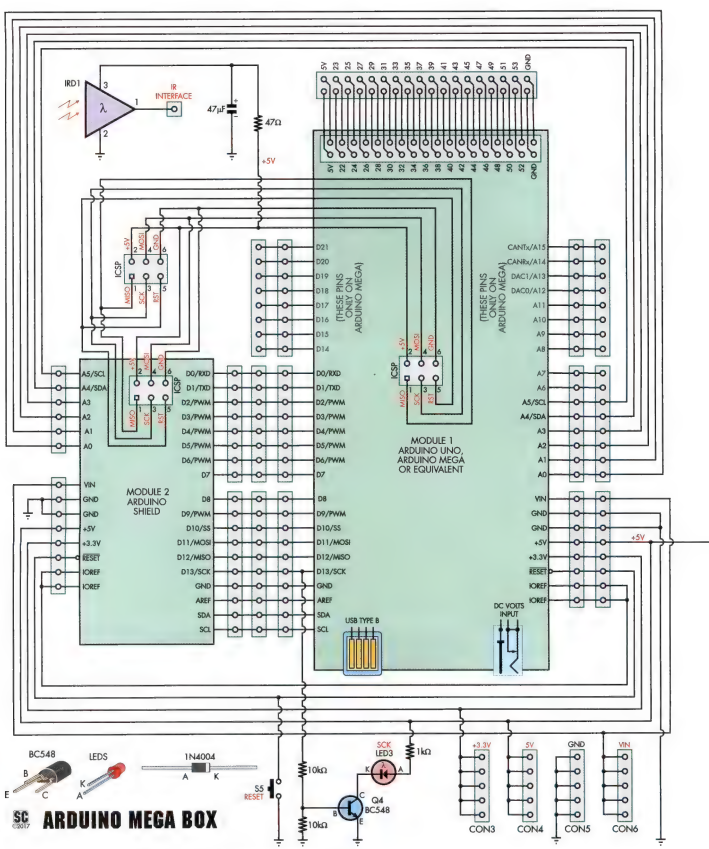
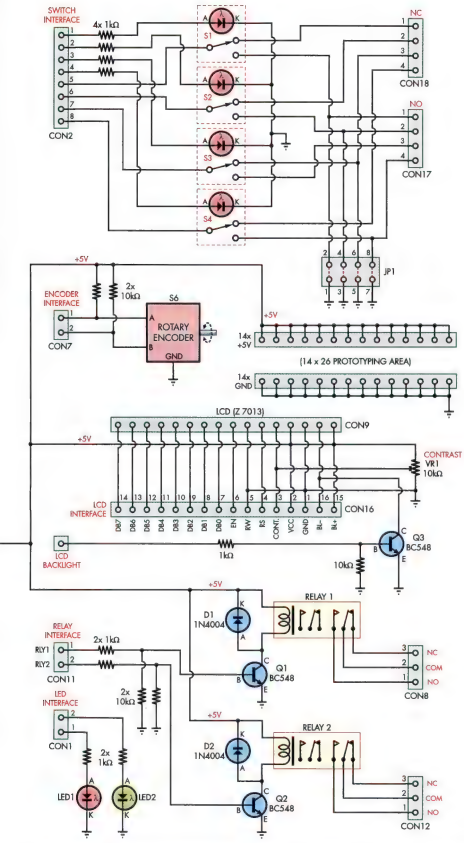


Fig.1: complete circuit diagram for the Arduino Mega Box.

(CON17 & CON18) are provided to connect to the normally open and normally closed contacts plus there are four jumpers (JP1) to short the normally-open contacts to ground.

This makes it easy to sense when a button is pressed since all you need to do is fit the shorting block on the jumper for a button and then wire the same button's common terminal to an Arduino digital pin. Set that pin as a digital input with internal pull-up and the pin will be high normally and is pulled low when the button is pressed.

Two extra general purpose LEDs, LED1 and LED2, are provided and would be most useful for debugging purposes since they are mounted in-



side the case. These are also provided with 1kΩ current-limiting resistors and have their cathodes connected to ground and their anode connections made via a 2-way header (LED interface).

There are also two on-board DPDT relays. One set of contacts for each relay is wired to a 3-way pluggable terminal block at the back of the unit.

Each relay has a back-EMF quenching diode across its coil and a BC548 transistor to drive that coil, along with 1kΩ base current-limiting resistors and 10kΩ pull-down resistors. A two-way header (Relay interface) allows you to wire these relays up to Arduino pins.

There are also three extra 3-way pluggable terminal blocks at the back of the unit which are wired to solder pads on the board and you could potentially wire these up to extra circuitry fitted to the prototyping area.

An infrared receiver is mounted at the front of the unit and it is powered from the 5V supply, with a 47Ω/47µF RC filter to prevent supply noise from affecting its operation. Its output is available on a 1-pin header (IR interface) and the signal can be decoded using the Arduino IRLib or other library.

There is provision for mounting a 16x2 LCD panel on the front of the unit and its 16 pins are wired directly to a 16-pin female header (CON9). The power supply (+5V and GND) pins are pre-wired for you along with contrast adjustment trimpot VR1.

Transistor Q3 allows PWM control and dimming of the backlight and it has a 1kΩ base current-limiting resistor and a 10kΩ resistor to ensure it stays off when not driven.

A rotary encoder (similar to a potentiometer but with a digital output) is provided for user input and is wired to a 2-way header (Encoder interface) with 10kΩ pull-ups to 5V on its two output terminals. It provides a "gray-code" output.

When rotated in one direction, the binary output at terminals A & B will have the following sequence: 00, 01, 11, 10, 00, 01, 11, ... while rotation in the other direction will give: 00, 10, 11, 01, 00, 10, 11, ... There are various Arduino libraries to help you decode this, including one called (predictably) "Encoder".

Construction

The main task when building the Mega Box is soldering all the components onto the main PCB. Fig.2 shows the overlay diagram which indicates where all the components go. Many of them are headers (mostly female but some male too).

Our sample Mega Box didn't come with much in the way of instructions and if yours doesn't either then this article should be a useful guide. You can also refer to our photos to see how the finished board should look.

Start by soldering all the low-profile components first (eg, resistors and diodes) then move on to the relays,

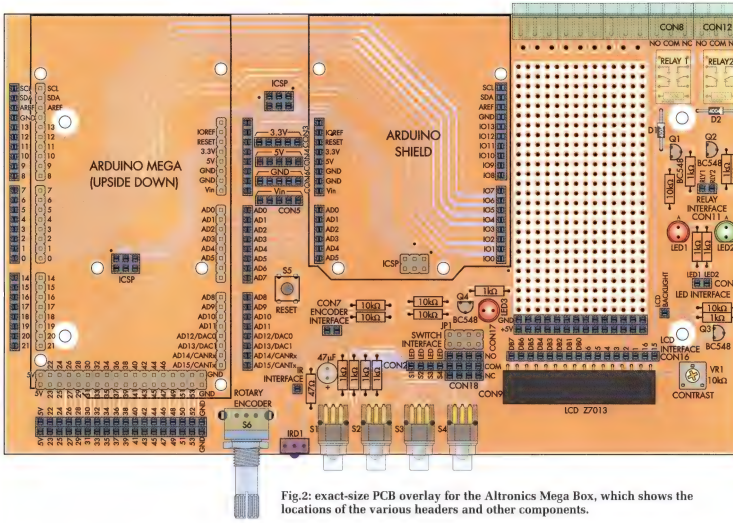


Fig.2: exact-size PCB overlay for the Altronics Mega Box, which shows the locations of the various headers and other components.

semiconductors and capacitor. Some components, such as the diodes, capacitor and relays, need to be fitted the right way around. For the diodes and relays, match up the stripe/line on the component to the one shown in Fig.2 or on the PCB.

For the three LEDs, the cathode (shorter lead) is on the same side as the flat portion of the plastic lens and should be matched up with what is shown in Fig.2 and the PCB silkscreen.

On the single 47µF electrolytic capacitor, the stripe down its side indicates the negative lead while the positive lead will be longer. The longer (positive) lead goes to the pad marked with the "+" symbol.

We found it easier to fit the switches, terminal blocks and infrared sensor before the headers and left the rotary encoder for last.

Note that the headers supplied may be longer than needed and you will have to cut the female headers to length and snap the male headers apart.

The various different header lengths required are listed in the parts list while the headers supplied are likely to be 40 pins long and so you can cut these up to form several of the smaller headers. You will be left with some spare headers at the end.

To snap the male headers, grab either side of the location where you want to snap them with two pairs of pliers (or just one pair) and then apply force to bend the header until it snaps. Double-check you will get the right number of pins before snapping.

The female headers are a little more tricky because you need to cut them apart using side cutters. This almost always destroys one pin so you should make the cut in the middle of the pin past the end of the last one you want to keep.

You can then remove the pin at the cut (if it didn't already fall out) and file any jagged plastic edges smooth.

Three dual-row female headers are required and while Altronics do provide a long dual-row header to cut apart, doing so is quite tricky; you really need a large pair of side-cutters. Instead you can cut and fit two single-row headers side-by-side.

Soldering the pin headers so they're straight can be tricky. Our tip is to solder one pin, then visually check it is flush and straight and re-melt the joints if it isn't, while applying a small amount of pressure.

Once it's straight, you can solder the other pins. You may also find that it helps to use a small flat piece of wood or similar material to support the header during soldering.

The right-angle female header is used as the socket for the LCD but note that you will have to solder a 16-pin male header to the back of the LCD panel to plug into this.

When soldering the rotary encoder, be sure to solder the two support pins on either side to prevent it from being ripped off the board.

An example program

Altronics provides a small example program on their website that showcases the LCD screen, rotary encoder, IR sensor and four illuminated push-button switches. You can download it

from **http://download.altronics.com.au/files/software_K9670.zip**

This program assumes you're using an Arduino Mega for the pin layout; you can use an Arduino Uno, like we did, but some of the I/O pin numbers will need to be changed. Here are the pin numbers we used with their software to work with the Uno:

- Encoder interface: pin A → D2, pin B → D3 (line 35)
- LCD screen: RS → D4, E → D5, DB4 → D6, DB5 → D7, DB6 → D8, DB7 → D9
- Backlight interface → D10 (line 46)
- IRD1 → D11 (line 53)
- SW1 LED → A3, SW2 LED → A2, SW3 LED → A1, SW4 LED → A0 (lines 60-63)

Before you can compile and upload the software in the Arduino IDE, you will need to install third-party libraries from the following sources:

https://www.pjrc.com/teensy/td_libs_Encoder.html

https://www.pjrc.com/teensy/td_libs_IRremote.html

You might run into conflicting names for the IRremote library as the header file shares the same name as the RobotIRremote library.

The easiest way to solve this problem without renaming one of the libraries is to just remove the RobotIRremote library from "C:\Program Files\Arduino\libraries" (or wherever the Arduino IDE is installed) temporarily. That's assuming it was already installed. Otherwise, it won't be an issue.

With the libraries loaded, you can upload the program to your Arduino board using a type-B USB cable and then make the various pin connections using male-male flying jumper leads (not included in the kit but see parts list for a suitable set from Altronics).

It helps to have a variety of lead lengths for tidiness but you will at least need a few that are more than 100mm long, if not 200mm to match the width of the PCB.

To figure out where the wires go, first refer to the list of connections above in reference to changes to the software (which is a complete list) but you can also refer to the photos in this article as a guide.

Note that when you run the software, you will need to adjust contrast trimpot VR1 for text to be visible on the LCD. We found that we had to wind it almost fully anti-clockwise for the text to be visible.

Parts List

1 double-sided PCB, coded K9670, 196.5 x 115mm
1 quarter-rack plastic instrument case with pre-cut holes
1 16x2 alphanumeric backlit LCD screen (LCD1)
1 infrared receiver (IRD1)
4 right-angle illuminated momentary pushbutton switches (S1-S4)
1 4-pin PCB-mount vertical tactile switch (S5)
1 10kΩ horizontal trimpot (VR1)
2 2A 5V mini DIL DPDT relays (RLY1,RLY2)
5 3-way PCB-mount right-angle pluggable terminal blocks (CON8,CON12)
1 rotary encoder with nut, washer and knob (S6)
1 2x18 pin dual-row female header
1 2x14 pin dual-row female header
2 2x3 pin dual-row female headers
1 16-pin right-angle female header (CON9)
1 16-pin female header (CON16)
2 10-pin female headers
8 8-pin female headers (including CON2)
1 6-pin female header
4 5-pin female headers
2 4-pin female headers
3 2-pin female headers (including CON7)
2 1-pin female headers
1 2x18 pin dual-row male header
1 2x4 pin dual-row male header (JP1)
1 2x3 pin dual-row male header
1 16-pin male header (for LCD1)
1 10-pin male header
5 8-pin male headers
solder
plus mounting screws and rubber pads for the case.
recommended: Arduino Uno or Mega; set of various male-to-male single jumper wires (try Altronics P1016); universal infrared remote control (eg, Altronics A1012); 4 shorting blocks (for JP1). All not included in the kit.

Semiconductors
4 BC548 NPN transistors (Q1-Q4)
2 5mm red LEDs (LED1,LED3)
1 5mm green LED (LED2)
2 1N4004 1A diodes (D1,D2)

Capacitors
47µF 16V electrolytic

Resistors (all 1/4W, 1% metal film)
7 10kΩ (brown black black red brown)
10 1kΩ (brown black black brown brown)

Also, note that their software doesn't adjust the LCD backlight until you turn the rotary encoder. You could connect the backlight control pin directly to 5V so that the backlight runs at full brightness all the time (as long as the unit is powered).

Or you can remedy this by adding the line "analogWrite(BL, 255);" after the line 69, which reads "lcd.begin(16, 2);". This will cause the backlight to start out at its highest brightness (if you haven't wired it directly to 5V, as suggested above).

The data sheet for the LCD screen used in this project is available from: **siliconchip.com.au/l/aahx**

The sample software will detect rotation of the front-panel encoder and display the rotation amount on the screen.

It will also pick up and display some infrared remote control codes, specifically, RC5 codes 0x001 - 0x004 and 0x801 – 0x804. These correspond to the buttons 1-4 on a universal remote set on one of the more common Philips TV codes.

When these buttons are pressed and are generating the correct codes, it will toggle on/off the corresponding LED in one of the four pushbutton switches.

Conclusion

The Altronics Mega Box is a very flexible system and can be used with virtually any Arduino shield (apart from a few that are too tall to fit in the case). Altronics supply a range of shields but it can be used with shields from other sources, too.

Building the Mega Box is not difficult so it's suitable for relative beginners. You can purchase the Mega Box kit (K9670) for $80 plus postage, or $75 each if you're buying two or more.

It is available from the Altronics website at **www.altronics.com.au/p/k9670-inventa-mega-box-for-arduino** or you could pick the kit up from one of their retail stores. **SC**

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DJI's AeroScope identifies and monitors drones

DJI, the world's leader in civilian drones and aerial imaging technology, has unveiled AeroScope, its new solution to identify and monitor airborne drones with existing technology, that can address safety, security and privacy concerns.

AeroScope uses the existing communications link between a drone and its remote controller to broadcast identification information such as a registration or serial number, as well as basic telemetry, including location, altitude, speed and direction.

Police, security agencies, aviation authorities and other authorised parties can use an AeroScope receiver to monitor, analyse and act on that information.

AeroScope has been installed at two international airports since April and is continuing to test and evaluate its performance in other operational environments.

Contact:
DJI
Tel: 1300 090802
Enquiries: aeroscope@dji.com

OKW's new enclosure Applications web page for engineers

OKW has added a new Applications section to its website to help design engineers specify the best enclosures for their electronics.

Each of the eight application sector includes a range of examples showing how easy it is to customise a standard plastic enclosure into a unique housing that enhances the electronics inside.

Examples feature links to the standard OKW enclosures used for each device so engineers can specify solutions more easily.

Technology featured in the new Applications section spans the range of OKW products: wearable, handheld, wired, wall mount and desktop enclosures.

OKW's customisation services are available even for low volume batches. Customers can specify bespoke colours, EMC shielding, CNC machining, lacquering, printing of logos and legends, membrane keyboards, display windows, adhesive foils, plastic and aluminium panels, installation and assembly.

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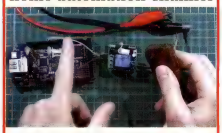
Website: www.okw.com.au

SuperHouse: Aussie DIY YouTube home automation channel



If you want to learn how to hack your house using Arduino, ESP8266, ESP32, Raspberry Pi and other common parts, have a look at the SuperHouse Automation channel on YouTube.

Most home automation videos on YouTube are just product reviews and showing you how to use commercial gadgets.

This channel is different: hosted by Freetronics founder Jonathan Oxer, it shows his ongoing journey to hack every aspect of his house and turn it into a SuperHouse.

Jonathan doesn't just show the end result. He works through the whole process, showing how he designs his projects and how they work.

He releases his designs and source code so that you can learn from it, and adapt them for your own home automation projects.

Topics covered include custom light switches, RFID, home automation system architecture, switchboard automation, MQTT, Power-over-Ethernet, CCTV, electronic door locks, electric window mechanisms, security sensors, robot lawnmowers, and watchdog timers.

Contact:
Superhouse
Web: youtube.com/user/superhousetv

AN EXTRA TECHY XMAS

GIFTS FOR SERIOUS MAKERS

Jaycar Electronics

OUR LOWEST PRICE EVER!

DUINOTECH MINI 3D PRINTER

TL-4076 **WAS $349**

Simple and affordable, print within minutes! Supports SD card and computer-based printing. 90 x 90 x 90mm print area. Supplied with white 1.75mm filament, SD card & reader, tools and user manual.

HOT PRICE $299

SAVE $50

Bluetooth

$199

INTRODUCING MBOT KR-9200

Makeblock Connect Your Dreams

Easy-to-assemble, entry-level robot that can avoid obstacles, follow lines, play soccer, and more. Control from your Smartphone or Tablet using the free app available, or program using simple drag-and-drop programming blocks or Arduino® IDE. Ages 12+.

LEARN ABOUT... ...SCRATCH

Scratch is a programming language where children can program and share their own stories, games, and animation with people from all over the world. Scratch allows programs to be constructed by dragging instruction blocks on a computer or tablet screen. It's intuitive and fun, and the results are instantaneous. mBot, Edison and Airblock can all be programmed with apps based on Scratch.

$99.95

Shown here using two units and LEGO® Technic blocks (not included)

MEET EDISON KR-9210

Compact, pre-assembled robot that is built to last. Pre-programmed with 6 robot activities set by barcodes, can be programmed using simple drag-and-drop programming blocks or a Python-like written language. Modular and easily expandable using LEGO® bricks. Ages 5+.

Edison

ENGINE CODE READER PP-2145

Plugs into OBD-II port and transmits speed, RPM, fuel consumption, etc via Bluetooth® to your Smartphone.

Bluetooth

$69.95

AC1200 WI-FI RANGE EXTENDER

YN-8372

Eliminate dead-spots in your Wi-Fi network and provide an access point to your existing wired network. Plugs straight into mains power point. 1200Mbps Dual band.

$99.95

2 WAY ACTIVE PA SPEAKERS WITH BLUETOOTH®

Indoor and outdoor active stereo speakers. Two way system, utilising powerful woofers and good quality silk dome tweeters. Sold in pairs.

5" CS-2470 **WAS $249 NOW $199 SAVE $50**

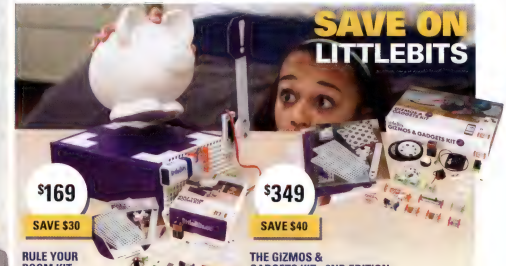
6.5" CS-2472 **WAS $299 NOW $249 SAVE $50**

FROM $199 pr

SAVE $50

Bluetooth

SAVE ON LITTLEBITS



$169

SAVE $30

RULE YOUR ROOM KIT

KJ-9120 **WAS $199**

Create touch-activated inventions to control your stuff. Prank mum, create games from scratch and defend your domain from intruders. Ages 8+.

$349

SAVE $40

THE GIZMOS & GADGETS KIT - 2ND EDITION

KJ-9100 **WAS $389**

Designed for young inventors to create and control their own app-enabled games, pranks, and crazy contraptions. Invent a remote-controlled car or a caterpillar that crawls with the tap of a tablet! 16 inventions. Ages 8+.

FOR OUR EXTENDED CHRISTMAS TRADING HOURS SEE OUR WEBSITE

GIFTS FOR THE YOUNG MAKERS

$79.95

ALL-IN-ONE LEARNING KIT XC-3900

This starter kit includes an Arduino-compatible UNO main board, breadboard, servo motor, light sensor, RGB LED, joystick, buzzer, LED matrix, line tracer, and assorted components and cables. All supplied in a handy carry case with dividers, and a quick start guide with links to online tutorials.

$109

MEGA EXPERIMENTERS KIT XC-4286

Contains an Arduino-compatible MEGA main board, a breadboard, jumper wires and a plethora of peripherals in a plastic organiser. *See website for details.*

NOW $99

SAVE $30

37-IN-1 SENSOR KIT XC-4288 **WAS $129**

Get more savings by purchasing this 37 modules-in-1 pack. Includes commonly used sensors and modules for Duinotech and Arduino®: joystick, magnetic, temperature, IR, LED and more. *See website for details.*

$49.95

CIRCUIT STICKERS STEM STARTER PACK KJ-9330

Uses copper tape with component stickers to allow kids to merge art and electronics. Includes copper tape, batteries, LEDs and heaps of templates and exercises, including circuits, switches. Even the box can be turned into a project! Ages 13+.

DRAW ELECTRONICS WITH CIRCUIT SCRIBE

A new way to teach kids the fundamentals of electronics. Kids can draw the circuits with the conductive pen and then watch them come to life. Each kit includes a detailed sketchbook with examples and templates. Ages 8+.

$119 KJ-9310 **MAKER KIT 17-PIECES**

$69.95 KJ-9340

$149 KJ-9300 **ULTIMATE KIT 32-PIECES**

$24.95

SALT WATER FUEL CELL ENGINE CAR KIT KJ-8960

Demonstrate the concept of a salt powered automotive engine. Assemble, add salt water, and off the car goes! 120mm long. Ages 8+.

$49.95

SOLAR POWERED ROBOT KIT KJ-8966

Can be transformed into 14 different functional robots. Ages 10+.

$49.95

GYRO ROBOT KJ-8957

Learn about gyroscope and how they are used in the real world. Up to 7 experiments - Robo Gyro, Gyro Compass, Gyrorector, Segway, Rope Walker, Balance Game & Flight Simulator. Ages 7+.

GIFTS FOR THE YOUNG SCIENTISTS

$9.95

PLANETARIUM EDUCATIONAL KIT KJ-8954

Build your own planetarium model. Paint it and add highlights and create a glow effect. Snap to build, no glue required. Ages 8+.

$9.95

POLARISING MAGIC PROJECT KIT KJ-9024

Learn about polarising light with this fantastic project kit. Includes five experiments. Ages 8+.

$9.95

AIR POWERED CAR PROJECT KIT KJ-9025

Learn about air pressure and how its powers can be harnessed. Components and instructions included. Ages 6+.

$9.95

AIR POWERED CONSTRUCTION KIT KJ-9023

Build a variety of vehicles and learn how air pressure can provide power. Includes components for three projects. Ages 8+.

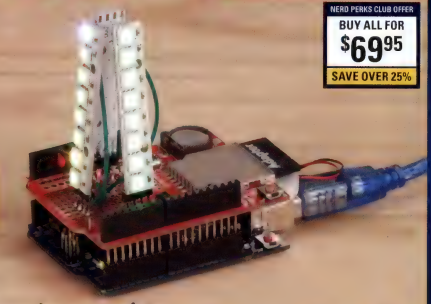
PROJECT OF THE MONTH

SINGING LED CHRISTMAS TREE

With Christmas on the way, we thought of creating a miniature Christmas tree using our LED Strip module XC-4380 complete with music playing from an SD card. The lights flash and twinkle in various colours. Add a little bit of Christmas to your desk or workbench! *Some soldering required!*

VALUED AT $98.65

NERD PERKS CLUB OFFER
BUY ALL FOR $69.95
SAVE OVER 25%



SEE STEP-BY-STEP INSTRUCTIONS AT: jaycar.com.au/singing-xmas-tree
SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

WHAT YOU NEED:

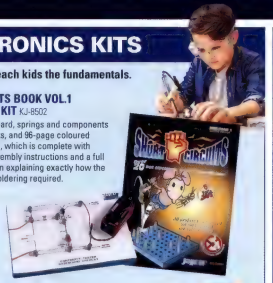
1 X UNO MAIN BOARD	XC-4410	**$29.95**
1 X DATA LOGGING SHIELD	XC-4536	**$19.95**
3 X LED STRIP MODULE	XC-4380	**$9.95**
1 X PIEZO TRANSDUCER	AB-3440	**$3.95**
1 X 8GB MICRO SD CARD & SD CARD ADAPTOR	XC-4983	**$14.95**

ELECTRONICS KITS

Great way to teach kids the fundamentals.

SHORT CIRCUITS BOOK VOL.1 AND PROJECT KIT KJ-8502

Kit includes baseboard, springs and components to make 20+ projects, and 96-page coloured Short Circuits Vol.1, which is complete with comprehensive assembly instructions and a full technical discussion explaining exactly how the circuit works. No soldering required.



$39.95

Batteries not included.

$12.95

ELECTRIC CURRENT EXPERIMENT KIT KJ-8901

Learn the common principles of electric current and magnetism. Requires 2 x D batteries, scissors, and tape. Ages 8+.

Batteries not included.

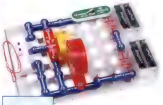
$27.95

12-IN-1 ELECTRICAL EXPERIMENT KIT KJ-8919

12 different experiments to construct that demonstrate various electronic principles. Requires 2 x AA batteries. Ages 8+.

SNAP ON KITS

Bright pieces. Easy snap together. No tools or soldering. Ages 8+.



$29.95

Batteries not included

$69.95

34-IN-1 KIT KJ-8983

Build up to 34 projects including electric fan, FM radio and learn parallel and series circuits. Requires 4 x AA batteries.

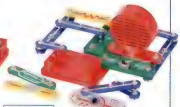
698-IN-1 KIT KJ-8985

Build you own helicopter, alarm clock, lighthouse, sound effects and more. 50 piece kit. Requires 4 x AA batteries.

$14.95

FM RADIO KIT KJ-8978

Create a fully functional selectable FM radio with this simple snap on kit. Requires 2 x AA batteries.



$15.95

BURGLAR ALARM KIT KJ-8974

Create burglar alarms and learn various circuits designs. Requires 2 x AA batteries.

EXTRA TECHY GIFTS FOR CHRISTMAS

CAR

$159

6/12/24V 15A BATTERY CHARGER
MB-3623

Suitable for gel and lead acid batteries. Microprocessor controlled for automatic 4-stage charging, including float charge. Safe to leave connected without risk to the battery.

- 5A @ 12V, 7A @12V/24V, 2A @ 6V/12V/24V outputs
- 230(H) x 170(W) x 140(D)mm

NOW $149
SAVE $10

140A DUAL BATTERY ISOLATOR KIT WITH WIRING MB-3686 WAS $159

Allows two batteries to be charged from your engine alternator at the same time. Emergency override feature. LED status indicator.

- 67(L) x 67(W) x 53(H)mm

See website for contents.

12V LEAD ACID BATTERY TESTER QP-2251

Tests most automotive cranking lead acid batteries, including an ordinary lead acid battery, AGM flat plate, AGM spiral, and GEL batteries.

- 6-30VDC voltage range
- 125(L) x 70(W) x 25(H)mm

$84.95

250 LUMEN WORKLIGHT ST-3273

Rugged, holds a high power 3W COB LED with magnetic base for convenient mounting. Torch function.

$14.95

HOME OFFICE

FROM $39.95

Dual-Band

DUAL BAND WIRELESS NETWORK ADAPTORS

Ultra compact, ideal for notebook computers being moved around and where a larger dongle may be easily knocked and damaged. Dual band 2.4GHz and 5GHz.

USB2.0 AC600 YN-8334 **$39.95**
USB3.0 AC1300 YN-8336 **$69.95**

$129

VDSL2/ADSL2+ WIRELESS MODEM ROUTER YN-8345

NBN-ready device. Equipped with a Gigabit Ethernet WAN port to provide an instant connection to a Fibre / NBN /UFB service when available. Multiple high speed Wi-Fi connections.

AC600 OUTDOOR ROUTER YN-8349 WAS $119

Provides Wi-Fi access in your outdoor entertaining area, carpark, shed etc. Dual band for speed up to 433Mbps. Single PoE connection. Functions as Wi-Fi repeater, access point, or router.

NOW $99
SAVE $20

Dual-Band

FROM $169

PANASONIC CORDLESS PHONES WITH BLUETOOTH®

Includes direct link to mobile, call block and do not disturb modes, app alerts, full speakerphone conferencing functions plus an answering machine.

1 CORDED & 1 CORDLESS HANDSET
YT-9014 **$169**

1 CORDED & 2 CORDLESS HANDSETS
YT9016 **$199**

SECURITY

$299

WI-FI ALARM SYSTEM WITH SMARTPHONE CONTROL LA-5610

Control it via touchscreen, wireless key fob remote or your Smartphone over your wireless network. Features SMS, email or auto-dial feature. 8 zones. Kit includes motion sensor, 2 x door/window sensors, key fob remote, batteries and power supply. Easy to install and use.

See website for more details.

BUNDLE DEAL INCLUDES ALARM AND:
1 X DOOR/WINDOW SWITCH
LA-5616 **$29.95**
1 X KEY FOB REMOTE
LA-5616 **$29.95**
1 X MOTION SENSOR
LA-5614 **$39.95**

ALARM + ACCESSORIES $348
SAVE $50

720P WI-FI IP CAMERA QC-3835

View live footage on your Smartphone with this high quality and easy to set-up camera. Download free App to quickly configure and monitor up to 15 cameras. Record videos to microSD card (available separately).

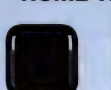
- Motion detection
- Infrared LEDs for night vision
- 2-way audio

NEW 2017

$119

HOME THEATRE

NOW $29.95
SAVE $20



Bluetooth®

KLIKR SMARTPHONE CONTROLLED IR REMOTE
AR-1956 **ORRP $49.95**

Turn your smartphone into a remote control. Organize all devices in your home via your smart phone and make it a remote control.

- Includes voice control

$54.95

Bluetooth®

WIRELESS AUDIO RECEIVER WITH NFC AA-2108

Streams music from your Bluetooth® or NFC® enabled device to your stereo system. Easy to setup and can be controlled from up to 10m away.

- 58(L) x 58(W) x 15(H)mm

$99

Bluetooth®

STEREO AMPLIFIER WALLPLATE AA-0519

Replace that bulky amplifier powering your ceiling speakers with this clever wallplate. Stream music from your Smartphone or connect audio to the AUX input. Includes 12V mains adaptor.

- 2 x 15WRMS (4Ω) Class-D amplifier

$179

CAT5/TCP/IP HDMI EXTENDER
AC-1734

Easily extend your HDMI source to a display up to 100m away using CAT5E/6 cable. Suits common router or switch. IR extender. 1080p.

ALSO AVAILABLE:
SPARE TCP/IP HDMI RECEIVER
AC-1735 **$99.95**

TECH TIP:

SINGLE BOARD COMPUTERS

With the advances allowing shrinking of technology, we can now fit a computer onto a single printed circuit board- the single board computer. There are many flavours of single board computers, from microcontrollers that are good for a single dedicated task, through to the Raspberry Pi and PCDuino which can run full multi-tasking operating systems.

An Arduino® UNO is a microcontroller single board computer, and it's actually comparable in processing power to the computer on Apollo 11. Arduino®'s are great for doing a single task, such as reading a sensor and displaying it. Because they are so simple, they are also a great way to learn programming, and are easy to connect to real world hardware.

A Raspberry Pi, on the other hand, is comparable to a Pentium based computer, and can run a full graphical desktop with apps like browsers and video players. From replacing an old computer to constructing a home surveillance system, the Raspberry Pi allows you to do more complex things than an Arduino®, especially if it involves data intensive operations like video, audio or connecting to the internet.

The PCDuino is similar to the Raspberry Pi in processing power, but adds the real world accessibility of the Arduino® by incorporating an Arduino® compatible pinout. Like the Raspberry Pi, the PCDuino also features HDMI, USB and Ethernet to connect with common peripherals.

SEE OUR ARDUINO® PROJECTS: www.jaycar.com.au/arduino

BEGINNER

DUINOTECH CLASSIC (UNO)
XC-4410
The Duinotech Classic is a 100% Arduino® compatible development board. Its stackable design makes adding expansion shields a piece of cake. Powered from 7-12VDC or from your computers USB port
- ATMega328P Microcontroller

$29.95

$19.95

SOLDERLESS BREADBOARD WITH POWER SUPPLY PB-8819
830 tie-point breadboard with removable power supply module. Includes 64 mixed jumper wires of different length and colour.
- 3V and 5V switchable output

$19.95

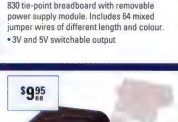
2 X 16 LCD CONTROLLER SHIELD
XC-4454
Allows you to create a user friendly interface for your project. Comes with a built-in 16 character by 2 line LCD display with backlight. Six push button keypad.

INTERMEDIATE

RASPBERRY PI 3B SINGLE BOARD COMPUTER
XC-9000
Quad-Core 1.2GHz CPU. 1GB RAM. Wi-Fi and Bluetooth. It can run Raspbian or Ubuntu (variaties of Linux) or even Windows 10 IoT core. Use it as a media player or even use the GPIO ports to interact with real world electronics.
- 4 USB ports
- HDMI
- Wi-Fi and Bluetooth®

SEE PAGE 8 FOR MORE ACCESSORIES

$74.95



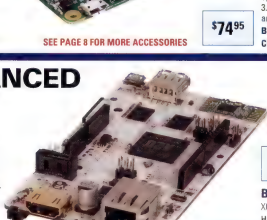
$9.95 ea

ENCLOSURES FOR RASPBERRY PI
Perfect for protecting your Pi. Includes openings for the USB, HDMI, Ethernet, 3.5mm, MicroUSB and MicroSD card and cooling holes. 2 colours.
BASIC BLACK XC-9002
CLEAR ACRYLIC XC-9004

FROM $99.95

TOUCHSCREENS WITH HDMI AND USB FOR RASPBERRY PI XC-9024
Compact, portable display to connect directly to your Pi. HDMI input and includes a touch interface.
5" XC-9024 **$99.95**
7" XC-9026 **$159**

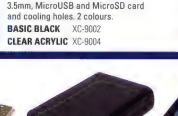
ADVANCED



PCDUINO V3.0 WITH WI-FI XC-4350
A high performance mini PC platform that runs on Ubuntu or Android ICS. Features onboard HDMI, USB, SATA, LVDS and Wi-Fi.
- Supported digital audio via I2C
- 121(L) x 65(W) x 15(H)mm

$89.95

SEE WEBSITE FOR MORE DETAILS: www.jaycar.com.au/pcduino



$19.95

BLACK ENCLOSURE
XC-4354
House your PcDuino in this enclosure for a safe and presentable appearance.
- Suits XC-4350

$89.95

7" LCD TOUCH SCREEN MONITOR XC-4356
- 1024 x 600 resolution
- LVDS screen with driver board
- 167(L) x 107(W) x 10(D)mm

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

4. NOW $159 SAVE $20

$64.95

1. **TRUE RMS MULTIMETER** QM-1321
- Non-contact voltage detection
- Autoranging
- CATIII 1000VDC
- AC/DC Current

6

2. **5 PORT USB CHARGING STATION** WC-7766 **WAS $69.95**
- Charge up to 5 Tablets or Smartphones
- Max power output 2.4A per port
- Total output 8.2A
- Includes 12VDC & 4A power supply

Accessories not included.

3. NOW $179 SAVE $20

3. **2MP WI-FI DIGITAL MICROSCOPE** QC-3752 **WAS $199**
- 10x - 200x magnification
- LED backlit stand
- USB interface for connection with PC
- Rechargeable battery

1

5

2

NOW $59.95 SAVE $10

$39.95

$199

4. **0-30VDC 0-5A REGULATED POWER SUPPLY** MP-3840 **WAS $179**
- Digital control & easy to read LED display
- Built-in over-current & short circuit protection
- 270(L) x 128(W) x 185(H)mm

5. **20MHZ USB OSCILLOSCOPE** QC-1929
- Ultra portable
- USB interface plug & play
- Automatic setup
- Waveforms can be exported as Excel or Word files
- Spectrum analyser (FFT)
- Includes 2 probes

6. **MAGNIFYING LED LAMP** QM-3544
- Great for arts and crafts, including model making
- 3x & 12x magnifying lenses
- Ultra bright LED lamp
- Mains powered

TECHY GIFTS FOR THE MODEL BUILDERS

$69.95

PLASTIC WELDING KIT TS-1331

Save money and repair small/medium cracks with this cordless welding kit.
- Cordless gas-powered welder
- Fast heating process
- 4 plastic filler types included

$54.95

ROTARY TOOL KIT TD-2459

Drill, saw, sand, polish, carve or grind. 210 piece with flexible shaft.

$24.95

MICRO ENGRAVER TD-2468

Engraves glass, ceramics, metals and plastics for security or insurance.
- Spins at 10,000 RPM

$14.95

FILE KIT TD-2128

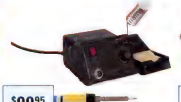
All have integrated plastic handles and come in a handy storage wallet. 10 piece.
- 162mm long each

TECHY TOOLS FOR YOUR CHRISTMAS PROJECT

400A AC/DC CLAMP METER QM-1563

Easy one-hand operation perfect for the working installer or tradesman. 600V, 4000 count. 400A AC/DC. Includes test leads & temperature probe.
- Autoranging
- 30mm jaw opening
- 200(H) x 66(W) x 37(D)mm

$129



$99.95

48W SOLDERING STATION TS-1564

Adjustable temperature (150-450°C), ceramic element and a lightweight pencil for fatigue-free soldering.
- Mains powered
- 150(L) x 115(W) x 92(H)mm

$39.95

LCD TYPE CALIPER TD-2082

Stainless steel. 5 digit LCD display. 150mm range. Supplied with a sturdy clip-lock case.

ALSO AVAILABLE:

BUDGET 150MM DIGITAL VERNIER CALIPERS TD-2081 **$13.95**

$29.95

GAMING CONSOLE TOOL KIT TD-2109

Includes tools for nearly every console and handheld on the market today - Wii, X-Box, Playstation etc.

EXCLUSIVE CLUB OFFERS:

FOR NERD PERKS CLUB MEMBERS

WE HAVE SPECIAL OFFERS EVERY MONTH. LOOK OUT FOR THESE TICKETS IN-STORE!
NOT A MEMBER? Visit www.jaycar.com.au/nerdperks

15% OFF
15% OFF
15% OFF
ALARM SIRENS & STROBES

NERD PERKS CLUB OFFER

SAVE 20%

GAMER BUNDLE
VALUED AT $62.90
INCLUDES:
USB GAMING KEYBOARD
XC-5130 **$29.95**
USB GAMING MOUSE
XM-5250 **$32.95**

ONLY $50

NERD PERKS CLUB OFFER

SAVE 30%

NETWORK CABLE TRACER
XC-5083
WAS $99.95
SAVE $30

NOW ONLY $69.95

NERD PERKS CLUB OFFER

20% OFF
30M ALARM CABLES*

*Applies to WB-1591 & WB-1596

NERD PERKS **SAVE 20%**

12VDC RELAY CARD KIT
KG-9142 **REG $12.95 CLUB $9.95**
5mA 3A.

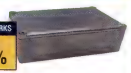
NERD PERKS **SAVE 30%**

DOUBLE GPO
PS-4065 **REG $29.95 CLUB $19.95**
With 2 x USB Charging ports.

NERD PERKS **SAVE 20%**

NON-CONTACT AC VOLTAGE DETECTOR
QP-2268 **REG $24.95 CLUB $19.95**
Detects voltages from 50 ~ 1000V.

NERD PERKS **SAVE 20%**



DIE-CAST ALUMINIUM BOX
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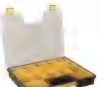

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MUSIC HALL mmf-1.3 turntable

It is a long time since SILICON CHIP reviewed a turntable – almost 20 years, in fact. Since then, vinyl records and turntables had experienced a long decline . . . but more recently quite a strong revival, with many groups and musicians releasing new vinyl recordings. To meet this new demand, a number of new turntables have appeared on the market, including the Music Hall mmf-1.3 reviewed here.

Review by Leo Simpson

The mmf-1.3 is a 3-speed belt-driven manual turntable fitted with an Audio-Technica AT-3600L moving magnet cartridge and an inbuilt RIAA preamplifier, providing line-level signals which can be fed to any modern sound system.

If you have a stereo amplifier or surround-sound receiver with its own RIAA preamplifier, you have the option of switching the turntable's outputs to the unequalised (ie, no RIAA equalisation or preamplification).

And while the turntable is belt-driven, it is powered by an electronically-controlled low voltage motor; probably a crystal-controlled brushless DC motor (often described as a DC servo motor) which provides speeds of 33.33, 45 and 78 RPM. This is a more elegant approach than used in most belt-driven turntables of the past which typically had a mains-power synchronous motor driving a stepped pulley to provide, usually, just two speeds.

There are several benefits in using the low voltage electronically-controlled motor. One of these is that the Music Hall turntable can be used virtually anywhere that 12V DC is available (OK, perhaps not in a car or on a boat!). It is not affected by the mains frequency (ie, 50Hz or 60Hz) as it uses a 12V DC plugpack.

And since it does not use a synchronous motor locked to the local mains frequency, the turntable's speed can be set to the exact value.

Here's the adjustment end of the tone arm, with the tracking dial at the rear and the anti-skate control closest to the camera. The tone arm is raised and lowered by the lever in the foreground.

The belt drive fits right around the turntable inner rim thence to the capstan, seen here in its access window. You have to remove the platter mat to gain access to this window but fitting the belt is neither difficult nor time consuming.

The presentation of the Music Hall turntable is very clean and simple: a shallow glossy back plinth supported on four large vibration-damping feet and fitted with a removable, moulded clear Perspex dust cover. Lifting the cover gives access to the 4-position switch which turns on the power and selects the three speeds: 33.33, 45 or 78 RPM.

The tonearm is a straight (not curved) design with a removeable EIAJ headshell and adjustable counterweight which allows the tracking force to be set between one and four grams (once it has been balanced). There is also an anti-skating force adjustment.

Note that since this is a manual turntable, moving the arm off the rest does not start the platter revolving – that is done by the speed selector/power switch. And nor does the platter stop revolving once the stylus runs into the central groove.

So the playing procedure is to start the turntable, position the stylus over the run-in groove and then flick the damped lift/lower level to gently lower the cartridge into the groove. At the end of play, you use the lever to raise the tonearm and then you move it back to the rest position.

This is simplicity itself and the way most record enthusiasts like it.

The Audio-Technica AT-3600L moving magnet cartridge is a middle-of-the-road model with a 0.6 mil conical stylus and a recommended tracking force of 3.5 grams. It does have a removeable stylus (AT-91R) so it can be replaced at some time in the future (after you have played a lot of records!)

By the way, the AT-3600L cartridge is not suitable for playing 78 RPM records. This will not affect most people since 78 RPM discs are quite rare – but if you did want to play them, to get the best results, you will need a cartridge with larger stylus, typically 3 mil.

The much smaller stylus of any cartridge intended for microgroove (ie, 33 and 45 RPM) records will ride in the bottom of the groove of 78 RPM records and be very noisy. In that case it is best to go for a dedicated 78 RPM mono cartridge such as the Audio-Technica VM670SP.

The turntable itself is a lightweight aluminium casting which has a thick rubber mat. Total weight of the platter and rubber mat is 785g.

We like the inbuilt preamplifier on the Music Hall turntable as it means its output leads can be plugged into any amplifier which can accept line level inputs, ie, with signal levels up to 1 or 2V.

Setting up

The mmf.1.3 turntable requires very little assembly out of the box. The main task is to install the platter on the spindle and make sure the belt is sitting on the motor shaft.

On upacking the mmf-1.3 turntable, we checked the speed of the turntable with the SILICON CHIP strobe disc and white LED strobe (December 2015) and found it was spot on at all speeds, straight out of the box. . .

. . . but if it proved to be slightly "out", it's a simple matter of adjusting the speed by holding down the push button for two seconds then turning the knob. Unfortunately, it is under the turntable so takes a bit of juggling to get to!

The mmf-1.3 is a fully manual turntable, which means it doesn't start operating when you lift the tone arm. The motor is controlled via the speed selection knob. Unusually, this turntable offers a 78RPM speed.

The rear panel sports the 12V DC input socket (plugpack supplied), a "GND" terminal and stereo RCA output sockets. You can choose RIAA line-level or "straight" phono output via the switch alongside the output sockets.

But anyone using a turntable for the first time would be wise to check that the tonearm is correctly balanced and that the tracking and anti-skating settings are correct. The instruction manual is quite good in this respect but anyone who has never set up a turntable would probably be wise to ask their audio retailer how it is done or have a look at video on the internet.

RCA leads are supplied so it is simply a matter of connecting these to the line inputs on your amplifier and you are ready to play. Before we did that, we checked the speeds of 33.33, 45 and 78 RPM using our 100Hz white LED strobe and strobe disc.

This showed that the speed settings were exact, with no drift of the disc strobe markings on any speed setting (see SILICON CHIP, December 2015: **siliconchip.com.au/Article/9640**).

If the speeds had been slightly off, the turntable has a facility for slightly increasing or decreasing the speed. This is a small pushbutton and knob on the underside of the turntable, at the lefthand side.

To change a speed setting, you first select the speed, then press and hold the button for two seconds and a LED comes on, You can then turn the knob to increase or decrease the speed to the desired setting. After that, you press the button again, the LED will flash and then turn off and the new speed setting will be stored by the unit's microprocessor.

We then set up the arm for balance, set the tracking for 3.5 grams and adjusted the anti-skating force accordingly, prior to testing the tracking ability of the cartridge using a variety of test records, some of which provide very stringent testing. In summary, the supplied Audio-Technica cartridge is adequate for average listening but records with very high recording levels will cause it to seriously mistrack.

By the way, we regard 3.5 grams as a fairly high tracking force – we tried it at 2 grams and found that this made little difference in tracking performance.

Our next series of tests involved frequency response and we were able to confirm that the fitted Audio-Technica 3600L cartridge has a response within ±2dB from 20Hz to 20kHz. Channel balance is within 1.5dB and channel separation averages between -15 and -20dB. The waveform on sinewaves is good. These tests were performed with the CBS STR100 test record.

Wow & flutter was quite low and difficult to measure, as was rumble. We would expect that result with this belt-drive/electronically controlled motor system.

And then it was on to playing records. This was the most enjoyable part of this review, being satisfied that the Music Hall turntable and cartridge performs well. The Audio-Technica has a clean, bright sound which does not emphasise surface noise and clicks – most important if you are playing older records which will inevitably have their share. You can buy it with confidence.

The Music Hall mmf-1.3 turntable has a recommended retail price of $499 inc GST.

For further information, contact the Australian distributors, Convoy International Pty Ltd, Phone (02) 9774 9900; website **www.convoy.com.au** SC

The mmf-1.3 is supplied with an Audio-Technica AT-3600L moving magnet cartridge, a middle-of-the-road model with a 0.6 mil conical stylus and a recommended tracking force of 3.5 grams. Note that this stylus will not play 78RPM records!

The hinged perspex lid on the mmf-1.3 turntable is completely removable, for those who prefer to operate that way (or to house the turntable in a hifi unit, for example). Size (without lid) is 435mm W x 106mm H x 367mm D.

SERVICEMAN'S LOG

Video trials and tribulations

Dave Thompson*

What did we do before USB flash drives became available. They certainly simplify the playback of digital content but even though they are not mechanical, I have found some unexpected reliability problems. We have become so used to the innate reliability of electronics equipment and it now it seem that can no longer be taken for granted. Still, if you are prepared to delve into these problems, the repairs can be quite simple.

Long-time readers of this column may recall the trials and tribulations I experienced when we purchased a new home-theatre system a few years back.

My main gripe was with disc region codes; after years of playing discs from all regions in our old, all-zones player, this new Blu-ray capable system would only play Zone 4 discs.

For those unfamiliar, powerful entertainment-industry lobbyists forced major manufacturers to implement a region coding system for DVDs, which meant, for example, discs produced for the American market wouldn't play on a system designed for the Australasian market.

This was apparently done to protect the industry from loss of income due to them not having control of when and where movies are released.

But what it really does is impose price-fixing and monopolising practices onto consumers, which is why there is barely any legal basis for disc zoning in most countries.

Thankfully, some manufacturers ignored these directives and consequently most of us had relatively easy access to region-free DVD players, at least we did until Blu-ray came along.

Once again, consumers on this side of the world are forced to buy inflated-priced discs long after northern-hemisphere buyers get to enjoy them, while they also have a larger variety of titles at subsidised-by-us prices.

Some good news is that there is a huge, quasi-underground network of dedicated reverse-engineer types working to provide region-free firmware for all brands of consumer disc players.

~IF YOU'RE PREPARED TO DELVE INTO THESE PROBLEMS THE REPAIRS CAN BE QUITE SIMPLE

Except that back then, there was no firmware available for our particular player, and while there might be something now, we've long-since worked around the issue.

For starters, we don't play Blu-ray discs, and most of the material we watch is digital content stored on USB media, so it isn't such a big deal any more.

The biggest blow back then was the fact we couldn't play any of the dozens of European (Zone 2) discs we'd picked up on our travels, including many titles that were never released on DVD in this region.

How these corporate bullies still get away with dictating what we can watch and when (if at all) escapes me, which is why I enjoy undermining their efforts to beat me down. Note that I'm not advocating ripping off studios or creators, I'm talking only about legally-acquired media.

When I discovered this LG system was region-locked, I very nearly returned it and likely would have, until I learned there were no region-free Blu-ray home-theatre systems on the market here yet to swap it with. Such is technological progress.

USB is the answer

This means the main way we watch content on our system these days is via a USB flash drive. The system is network capable, and "internet ready" but the proprietary WiFi dongle it requires is so ridiculously overpriced I refuse to buy it.

Running a permanent cable is not feasible either, given the location of

Items Covered This Month

- Blu-ray player and HandyCam
- 360° passive infrared sensor repair
- Fuse blows, stove goes

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Email: dave@pcanytime.co.nz

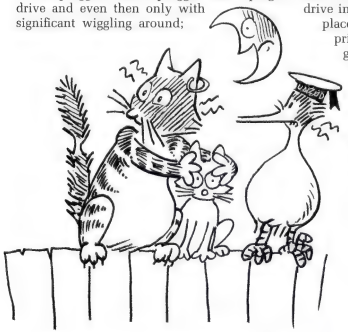
the system and the distance from the nearest network switch.

It's not really a bother; we simply load up what we want to watch on a flash drive and put it into the single USB port in the front of the player; after a few seconds we have a basic file-system we can surf around using the remote and choose the file to play.

However, of late, we've had a few problems with the drives. Initially, I thought we might have worn out one of them, as it would "drop out" once or twice and we'd have to re-insert it and fiddle about to try and find where we left off. This was annoying but with it only happening every now and then, not a show-stopper.

Eventually I bought a couple of higher-capacity flash drives and was mildly peeved to find one sporadically not being recognised by the system.

Eventually, it got to the point where none of the drives would register until we plugged and re-plugged the drive and even then only with significant wiggling around; obviously there was something amiss.



Like all servicemen, I'm always ready to drop everything and head to the workshop. This particular night we were hyped to watch a particularly good show and the air was rendered blue when we discovered that none of the flash drives would "play".

After unplugging the raft of cables and plugs connecting the base unit to the speakers and peripherals, I repaired to the workshop to do some, er, repairs.

Opening the thing up was simplicity itself. Six small screws held the metal "top-hat" style metal case onto the base. The shape of the cover required me to splay the bottom edges out to lift it straight up and away to reveal the interior.

The USB socket was in plain sight, though due to the way it was situated, the soldered connections were underneath the board. So another half a dozen screws needed to be removed and a few flying leads and plugs removed before I could flip the PCB over.

Immediately I could see the problem: every one of the socket's four solder joints had a tell-tale dark ring around the lead coming through the board. Flexing the socket widened these rings on one side and compressed them on the other, indicating that all were fractured and would only electrically connect when the socket was pressured this way or that.

No wonder the programs were dropping out and it was hard to get the drive initialised in the first place. In fact, I was surprised it worked at all, given the gaps in the solder joints.

By this time my soldering station was well up to temp and a quick application of heat and a press of the button on my Goot solder sucker soon had each pad on the PCB and the socket's leads clear of old, dry solder.

I sweated in each joint with a fresh pool of solder and flipped the board over to check it had gotten

right through to the opposite side as well. It all looked good and within 10 minutes the screws were back in and I was in the lounge plugging all those cables back in.

From that point to this, any flash drive inserted registers almost instantly and is ready to go within seconds. Interestingly, I never recalled it being that good before, so perhaps it had been defective right from the word go.

There was certainly very little solder on those connections and a lot less that it has now. I guess this is the price we pay for lower-cost electronics in general but surely a bit more solder all-'round wouldn't break the bank.

HandyCam challenge

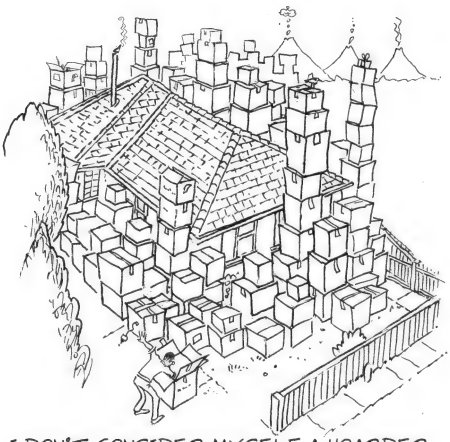
Another challenge I faced recently was with my Sony HandyCam. While this is now about 10 years old, it is still a pretty good little camera and since I need a decent camera for my new YouTube venture, it was, as the Americans say, a "no-brainer" to dust it off and charge it up, ready for testing.

Over the years, I've taken a lot of video and stills with this camera. The 4-megapixel sensor might be a bit lame compared to what's available now but back then it was the business.

However, since in all those years I'd never dumped many of the photos or videos I'd taken from the 40-gigabyte hard disc, it was pretty full.

I recently recorded a couple of test clips with it and while only HD rated (720p), it will do me fine, until I can afford to shell out for a mirrorless, DSLR FHD camera that can do 1080p at 60 frames a second. Best tools for the job, right?

And therein lies my problem; the display shows a mere 18 minutes of hard-disc space remaining if I continued filming at the current resolution. To do anything serious, I'd need to



I DON'T CONSIDER MYSELF A HOARDER

dump the data on the camera's drive to one of my computers to free up a bit of space.

To accomplish this, Sony deemed it necessary to provide just one way of getting the files from the camera to a computer. Actually, there were two, possibly three ways, but I'll talk about that in a minute.

The problem was that in the shift to this new house, I've misplaced the supplied USB docking station the camera requires for a computer connection.

A quick look on the local auction sites didn't show any of the correct model for sale and according to references I found in forum posts regarding the subject, Sony have long-since stopped making and selling them. I also tried the usual Chinese online sources but there was nothing there either.

Convinced the docking station must be packed away in one of the dozens of boxes we still hadn't un-packed, I spent an entire weekend opening and sorting through so much extraneous rubbish that I was almost ready to dump it all straight into a skip.

I don't consider myself a hoarder and it isn't like I have to sleep standing up because every square metre of floor space is packed to the ceiling with swag but I do appear to have a lot of stuff I could well do without.

How I ever accumulated it all is a mystery. I can't recall buying a lot of it but it's there so I must have acquired it at some stage! Annoyingly, though, the docking station was nowhere to be found.

It was time to get creative. I blew the dust off my eBay account and hit the international auction sites to try and find one. The model I was after is the DCRA-171, made especially for my camera and a handful of other models. I found a couple, and was quite excited until I saw they were asking as much as US$95! That seemed a little steep, but I guess the price reflected just how hard to find these things were becoming.

After a bit more digging, I found one listed on the UK eBay site, for a much more reasonable £12, roughly NZ$25. I placed a bid after discovering they shipped overseas and even with shipping included, I'd be looking at about fifty bucks, still a bit high but realistically a much more reasonable amount.

The day of the auction came and went; when checked I discovered it had been purchased by someone else after a small bidding war for £35! This was getting tiresome.

It was about this time I noticed the camera also has a memory card slot. It is tucked away under the fold-out LCD screen and I'd never really noticed it before. This could be the solution. If I could still get a memory card to fit it, perhaps I could transfer the files from the camera's hard disc to the flash media and transfer them to the computer using a card reader. That sounded much more feasible.

I checked AliExpress and the MS-Duo cards the camera took were as cheap as, er, chips and it was no big deal if I had to wait a little while for it.

However, before I committed myself, I checked the camera's user manual and believe it or not, there is no way to transfer files from the hard drive to the memory card. I could do it the other way, from the flash drive to the hard disc, but not the way I needed. Darnit!

However, while I was looking on AliExpress, a camera caught my eye; it was one of those "action cameras" with all the cases, mounts and trimmings for just US$45. Cheaper than a docking station and with claims of 4K video at 25 frames per second, this seemed an ideal solution to my problem.

The only extra hardware this camera required was a microSD card and as I already had a couple on hand, I wouldn't need to buy anything else.

Sadly, I put the Sony back in the drawer while I waited for this one to arrive. I had plenty else to do in the meantime so I went on with that instead.

The camera duly arrived and I was impressed. It came with a clear, water-proof housing and a dozen other adaptors and mounts for helmets, handlebars and tripods. I mounted it onto my tripod and set about testing it out.

The first thing I discovered was that when set to 4K recording, it could only manage about one or two frames per second; a long way away from the 25 FPS claimed. No real harm; I wouldn't record in 4K anyway, so it was moot.

However, after further trials, I discovered the camera could only manage a maximum of 23 FPS at 720p and while truthfully I had no right to expect a 4K, 25 FPS capable camera for that money, I still felt burned.

And then there is the audio quality; the on-board mic level was poor and while this was to be expected when mounted inside the water-proof case, even when sitting outside the case the

audio capture wasn't great. If I did use the camera, the cover could be handy as at times it would be working in a dusty workshop environment.

As a potential workaround, I carefully bored a 2mm hole through the plastic case adjacent to the mic aperture in the camera's case – after all, it wouldn't be going under water. While this improved things a bit, it wasn't enough to allow me to record without an external mic, which the camera doesn't have facilities for anyway. Boy, this YouTube stuff is difficult!

With that camera a dead duck, I returned to the Sony and the web. I eventually stumbled upon a schematic someone had drawn up depicting the DCRA-171 docking station's proprietary USB connections. This was more like it; this might enable me to solder a cable or connector directly to the camera's PCB.

Though heartened, I was reluctant to pull the camera apart. I remembered last time I repaired it, how complex it was and this time I would need to strip it down even further, right to the bottom of the camera.

I took my time and after careful parts removal, finally reached the socket. To my dismay, the connector markings bore no resemblance to the diagram. Nothing tallied and the two components seemed miles apart, with nothing referencing the other.

There were no pin numbers visible and though I had a good go with a multimeter, trying to 'ring out' the ground, +5V and data + and - leads and match anything at all to the diagram, it was to no avail. Annoyed, I reassembled the camera, wondering where to go from here.

Then, I got lucky. As if on cue, an email notification popped up saying a keyword search I'd set up on a local on-line auction site had a hit. I immediately went online found a guy selling a DCRA-171 docking station for $20 plus shipping; I bought it on the spot.

It arrived a few days later and I hoped like hell I'd not caused more problems mucking around with the socket. I needn't have worried. The USB connected straight away and I cleared the files from the drive. Now: lights, camera, action!

360° PIR Sensor Repair

When something breaks, usually the worst case is that you have to replace it with a new one. B. P., of Dundathu, Qld did just that, only to find that not only was the brand new unit broken and would need to be fixed, it also had to be modified to fit where the old one had been mounted! Here is the story as he tells it...

When we built our new house in the early 1990s, I installed a 360° PIR (passive infrared) sensor underneath the front verandah, near the outside edge, to operate two coach lights on the front wall of the house (either side of the front door) automatically whenever someone approached.

The sensor only worked for a short time. I wondered why it had failed when it was still nearly new, so I removed it and inspected it. I found that the circuit consisted of a 270Ω 0.5W resistor in series with an X2 capacitor, followed by a bridge rectifier, zener diode and electrolytic capacitor to supply the low voltage to operate the unit. This is the same arrangement used in many low-power mains-connected devices.

It was the inrush current limiting resistor that had burned out. Luckily, the resistor had burned out in such a way that I could still read the value. I replaced the resistor with the same type and as a precaution, I wrote its value on the PCB, just in case it ever needed replacing again. The unit then worked again for a short time, before failing yet again and it was the same resistor that had burned out yet again.

I could see that this was going to be an ongoing problem, so I decided to replace the resistor with something more substantial. I looked through my stock and decided to use two 150Ω 1W resistors in series, as that was the closest I could find at short notice. The total was 300Ω, but it should work OK.

Well, that was obviously the right thing to do as the unit then worked for over 20 years with no issues, until one day when my wife said that it had stopped again. I took the plastic cover off and it promptly disintegrated in my hand due to its old age. So clearly, I needed to replace the whole thing, no matter what was wrong with it.

A couple of days later, we were in Bunnings so I headed to the electrical department and we soon spotted a similar unit on the display wall. However, when we checked the shelf, there were none in stock.

In a stroke of luck, the company rep for that brand was in the store doing

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a stock-take, so she grabbed a ladder to scan the unit on the wall to check the stock. On her way up the ladder, she spotted a box at the back of the top shelf, with the last remaining 360° PIR sensor, so we bought it.

Later, when I went to fit it, I checked the light switch for the old sensor and it was off, so it's possible that the old sensor was still in working order.

The problem had been that a storm one night, some time back, kept tripping the sensor and turning on the coach lights, which are near our bedroom, so it had been turned off and we then forgot to turn it back on later.

Note to self: next time, check that the unit is switched on before taking it apart to fix it!

Anyway, I got set to fit the new sensor and the first problem was that I needed to drill new holes in the Villaboard ceiling because the new sensor had a different mounting arrangement to the old one. I screwed the base to the ceiling with the idea being that the PIR sensor itself would then clip into the base.

But when I grabbed the unit itself, I could see that there was a problem because the three-wire terminal block protruded and would foul the ceiling. That would mean I would have to drill a large clearance hole in the Villaboard, which I did not want to do. I can't say I was very impressed with the design at that stage.

However, I was able to cut the terminal block into three individual terminals with a Stanley Knife so that the terminals could lie flat and therefore fit in the recess in the back of the unit. Problem solved.

As I proceeded with the installation, I thought I would set the three adjustments: LUX (light threshold), SENS (movement sensitivity) and TIME (light on-time) to the values I wanted.

I set SENS to maximum and LUX to a daylight level so I could test the unit after installation. But when I went to set the time to the minimum, the small adjusting knob kept turning and did not stop.

Something was obviously wrong there, so I took the unit down and opened it up. The two sections of the case are held together by four clips around the edge of the unit, so I was able to separate them without too much trouble.

A closer look revealed that someone had tried to adjust this unit on a previous occasion and turned the adjuster hard against the stop and broken off the small square plastic extension of the knob that sits inside the pre-set pot.

What to do? I could not take the unit back for exchange because it was the only one in stock and besides that, I had already modified the terminal block. There were three choices: bin the unit, put it up with the broken part or try to repair it. I quickly ruled out the first two, so I had to work out a way to repair this small plastic knob.

I needed to think of something to add a new square extension to it, in order to restore it. I tried to think of something of the right size with a square cross-section to replace the broken piece of plastic with and then I realised a matchstick would do the job. I cut the head off a match and compared it to the broken piece; it was an almost perfect match.

So I removed the knob and very carefully drilled a hole where the stop had broken off, using my cordless drill at minimum speed, while holding the knob in my fingers. I started with a 1/16-inch drill, then a 5/64-inch drill, then a 3/32-inch drill. The resulting hole was a tight fit for the matchstick shaft, so I glued it into the hole using a drop of super glue.

I then trimmed the match to length carefully with a fine-tooth hacksaw blade and reassembled the unit. This somewhat unusual repair resulted in the restoration of the sensor to "good as new" condition and saved it from the bin. Unfortunately, these days, things are not made to be repaired, so you often have to be crafty when it comes to repairs.

I was then able to adjust the delay time to just above the minimum setting and soon had the unit mounted in place. Job done. I turned the power and light switch back on and went outside. The lights were on, but they stayed on for over a minute, so I started thinking that maybe there was a fault with the unit. Then the lights went out.

That was a relief as it just meant that the TIME adjustment was set too high. I set it to the minimum and stepped aside. The lights stayed on for eight seconds, so that was too short. I advanced the setting small amount and this resulted in a 15-second delay before the lights went off.

I was aiming for 20 seconds, so I adjusted the setting by a hair and stood aside. The lights then stayed on for well over a minute, which was far too long.

I set the adjustment back by a hair and this resulted in a 15-second delay again. This adjustment was far too sensitive, so I just settled for the 15-second delay. I then set the LUX setting to a suitable level for night-only activation and the job was done.

Exploding circuit board in my stove!

R. B., of Kambah, ACT was cooking a stir fry when his induction cook-top abruptly gave up the ghost. Luckily, the repair was reasonably straightforward and economical, considering the high purchase price of the unit...

Recently, I was cooking the evening meal on my Belling stove which has an induction cook-top. About halfway through cooking, the stove went BANG and the cook-top stopped working. I rushed around and found a portable butane cooker to complete the stir-fry.

After dinner I searched out the warranty and purchase documents for the stove; it had a 2-year warranty but the purchase was three years ago. Not good.

Knowing that the induction cook-top was the most expensive part of the stove, I was thinking this problem was going to be expensive. With this in mind I was keen to investigate the problem and possibly repair it. To this end I began to dismantle the stove.

It was not too hard to remove the glass top as a unit, before which I had pulled the fuse on the stove circuit. To remove the top required removing four screws at the back and disconnecting the power supply to the induction top and also unplugging the signal wire connections to each of the

Servicing Stories Wanted

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Please be sure to include your full name and address details.

control knobs on the front of the stove.

Laying the stove-top upside down, I was able to remove the screws around an aluminium tray which held the induction unit under the glass top. Turning the tray over it, was a simple matter to click out the induction coils and unscrew their cable connections to a circuit board.

The coils had to be removed to get to the Torx screws which held a plastic tray to the aluminium tray. This tray has three circuit boards clipped into it. Once the plastic tray was free it was a simple matter to clip out the circuit boards after marking and disconnecting the power cables and digital cable connecting to a small control board.

Looking for the cause of the BANG, on removing a power filter board I found that underneath was a large black soot and vapourised copper splatter on the board and in the plastic tray.

After scrubbing all of the splatter off the board it was clear what had happened. This board had a narrow track, with slots punched each side, designed to be the fuse. To support this analysis, on top of the board paralleling this track is provision to install a proper 240VAC-rated fuse.

Therefore to make the repair I installed an appropriately-rated glass mains fuse. There was another similar fuse on the other edge of the board which I also replaced with a glass fuse and then cut the copper track. Having repaired the fuse I had to then determine the reason for the fuse blowing.

On the induction heating coil driver board, there is a power transistor and large capacitor for each cook plate. Checking the large transistors with an ohmmeter, I found that one transistor was clearly fused (zero ohms between all leads).

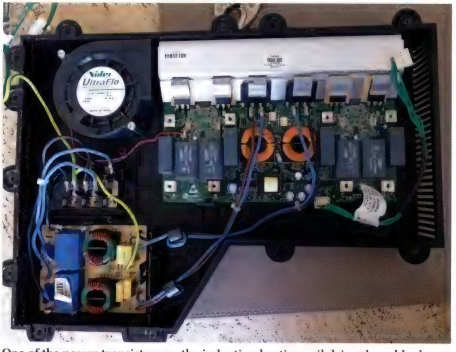
On looking at the board markings the three leads on the transistor were marked C, E and G – odd; I have not seen a transistor marked this way. Using a solder sucker I unsoldered this transistor, and to remove its heatsink I was able to use a long clamp to pull the clip sideways to cause it to pop out of the groove; I did not want to deform the spring in the clip so that it could be reused.

Once the transistor was out I could read the markings "TOSHIBA 40RR21". Finding the datasheet on the internet, it is an Insulated Gate Bipolar Transistor (IGBT) and "Dedicated to Voltage-Resonant Inverter Switching Applications". The resonant circuit appears to be formed with a large capacitor and the induction coil for each hot plate.

The underside of the stove-stop which shows the various induction coils and their cable connections to the circuit board below. These coils were removed so the aluminium tray could be unseated and the circuit board freed.

Being a specialised device I was not so confident I would be able to find a replacement. However, a Google search found a replacement at www.aliexpress.com

My stove cook-top is now working as before, except next time I should not have to clean up all the spatter and a fuse blow-out will be safer. SC



One of the power transistors on the induction heating coil driver board had fused and needed to be replaced.

Build your own Super-7 AM RADIO RECEIVER

Part II – by John Clarke

In this second and final article on the new Super-7 AM Radio, we show you how to assemble it, then align it for best performance. Then you can put it into its superb acrylic case . . . and your friends won't believe you built it!

Assembly is not at all difficult – everything is mounted on one large PCB and we don't use any SMD components – so it's standard soldering all the way.

And don't be put off by alignment: it's not hard to do and can be done using quite basic equipment, as we will explain shortly.

Of course, it can also be even better using specialised equipment, such as the Dead-Easy DDS Superhet IF Alignment Unit we published in the September 2017 issue (www.siliconchip.com.au/Article/10799).

As its name suggests, this makes alignment, or adjustment of the IF coils, on the Super-7 AM Radio . . . dead easy! (see the panel on page 73).

But if you can't justify building a device such as this, there are other ways to do it; maybe not quite so simple or elegant but effective nevertheless. We will cover other approaches to align the radio set shortly.

There are a number of test points on the circuit board which can be used for voltage measurements or to provide signals to be displayed on an oscilloscope.

We will show some typical waveforms in this article, so you will know what to expect.

Fortunately, you don't need an expensive 'scope for this – indeed, there are any number of 1MHz bandwidth

kit models available on ebay and similar (ie, you build them first!) for well under $100.

And if you're at all into hobby electronics (or above) you really do need an oscilloscope on your bench. Spend a little more and you can get a really good, higher bandwidth scope which will suit your needs for many years.

Construction

The Super-7 AM Radio is built on one double-sided PCB coded 06111171 and measuring 313 x 142.5mm.

It is housed in a multi-piece acrylic case, available from the SILICON CHIP Online Shop. This also includes a transparent tuning dial. Station call signs (eg, RN for Radio National) and frequency markings that are screen-printed on the PCB can be seen through it.

The Super-7 AM Radio uses some special AM radio parts. These include a coil pack, a mini tuning gang capacitor and ferrite rod with coil. Otherwise, most of the parts are pretty common – you may have many of them in your "junk" box.

Fig.1, the circuit, was published last month. Fig.2 (overleaf) is the overlay diagram and this shows where all the components go on the PCB. Use this (and the photos) as a reference while following these instructions to fit the components to the board.

Begin construction by installing the resistors. Their colour code table is shown on page 70.

We suggest that you also check each resistor value with a digital multimeter before it is inserted – some colour bands appear close to others (eg, red, brown and orange) so it is always wise to double check, especially before you solder them in!

Resistors are not polarised – they can be inserted either way into the board but it is a good idea to install them so that their colour codes all align in the same direction. This makes it so much easier to check their values later on.

Fit the PC stakes for the GND (TP GND), two near CON2 (for the speaker), one at TP1 and five for VR1. Three of the PC stakes for VR1 are to wire it to the board, while the remaining two are to solder to the potentiometer body to hold it more securely. This pot is installed later.

Next, install the capacitors. There are three types used in the circuit. One type is MKT polyester (plastic) and these can be recognised by their rectangular shape. These are not polarised. The second type is ceramic and these are also not polarised. Fortunately, they are all the same value too, so you can't get them mixed up!

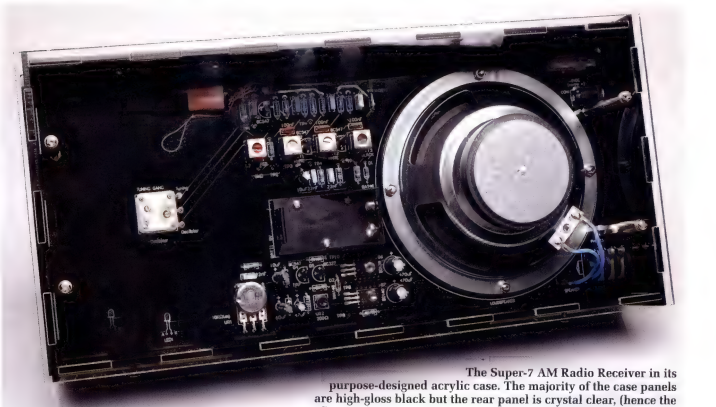
Generally, small capacitors are not marked with their actual value – instead, they use a code which you need to decipher. We make that particular task easy with the small capacitor code table, also on page 70.

The third type of capacitors used in this project are electrolytics – they *are* polarised and must be inserted the right way around – follow the markings on the PCB overlay. Electrolytics are (usually) cylindrical in shape, with a polarity stripe along one side for the negative lead. The opposite (positive) lead is usually the longer of the two.

Almost invariably, electrolytic capacitors will have their actual value printed on them, along with their voltage rating.

One point which often confuses beginners: it is normally OK to use an electrolytic capacitor (or indeed any capacitor) with a voltage rating higher than that specified, as long as there is room (capacitor size normally increases with voltage). However, it is **not OK** to use capacitors with a lower voltage rating than that specified.

For example, if a circuit calls for a 10µF, 16V electrolytic capacitor, you can normally use one of the same value and type – 10µF electrolytic –with a 25V, 35V or even higher rating, as long



The Super-7 AM Radio Receiver in its purpose-designed acrylic case. The majority of the case panels are high-gloss black but the rear panel is crystal clear, (hence the reflections), just so others can see your handywork in all its glory!

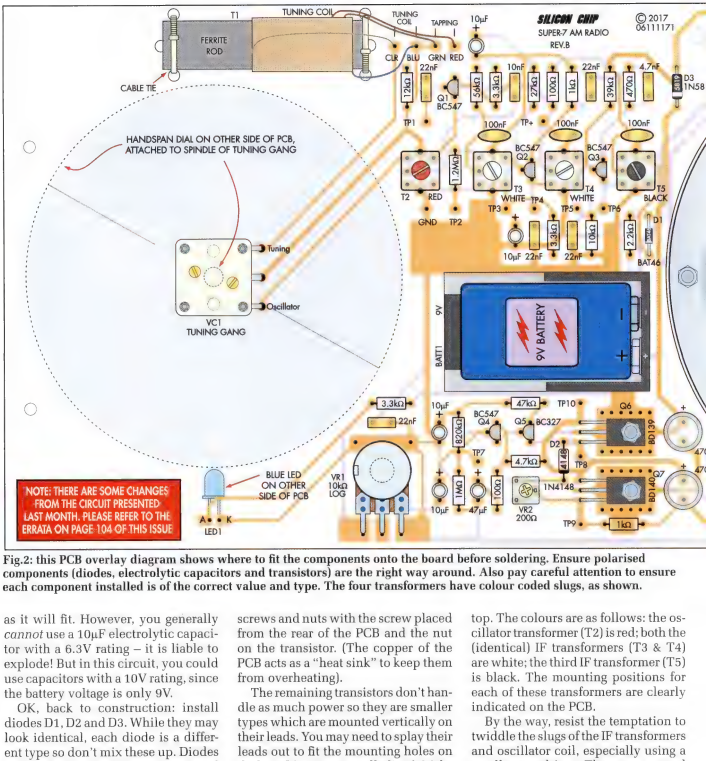


Fig.2: this PCB overlay diagram shows where to fit the components onto the board before soldering. Ensure polarised components (diodes, electrolytic capacitors and transistors) are the right way around. Also pay careful attention to ensure each component installed is of the correct value and type. The four transformers have colour coded slugs, as shown.

as it will fit. However, you generally *cannot* use a 10µF electrolytic capacitor with a 6.3V rating – it is liable to explode! But in this circuit, you could use capacitors with a 10V rating, since the battery voltage is only 9V.

OK, back to construction: install diodes D1, D2 and D3. While they may look identical, each diode is a different type so don't mix these up. Diodes are also polarised. The polarity band or stripe, which indicates the cathode (k), is oriented toward the bottom of the PCB as shown on the overlay diagram.

The transistors go in next. Again, make sure you put the correct transistor in each position. Transistors Q6 and Q7 are mounted horizontally with leads bent over at 90° so that their holes line up with the holes in the PCB.

The Q6 & Q7 transistor bodies are attached to the PCB with M3 x 10mm screws and nuts with the screw placed from the rear of the PCB and the nut on the transistor. (The copper of the PCB acts as a "heat sink" to keep them from overheating).

The remaining transistors don't handle as much power so they are smaller types which are mounted vertically on their leads. You may need to splay their leads out to fit the mounting holes on the board (eg, using small pliers). Make sure the "D"-shaped packages (looking down on them) go the same way around as shown on the overlay diagram.

IF transformers

Now you can install the oscillator and IF transformers. They will only go in one way with three pins on one side and two on the other.

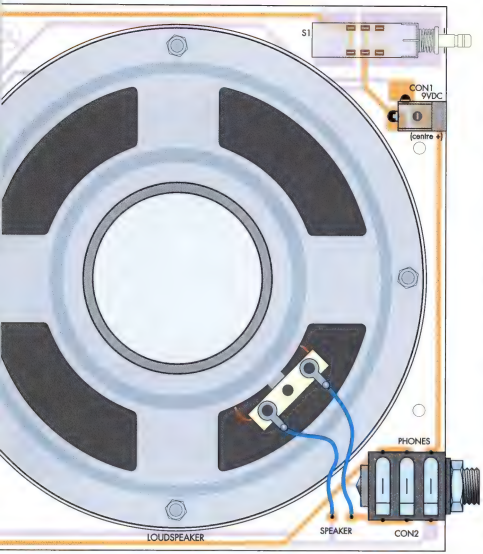
However, these all look the same except for the colour of the slug at the top. The colours are as follows: the oscillator transformer (T2) is red; both the (identical) IF transformers (T3 & T4) are white; the third IF transformer (T5) is black. The mounting positions for each of these transformers are clearly indicated on the PCB.

By the way, resist the temptation to twiddle the slugs of the IF transformers and oscillator coil, especially using a small screwdriver. There are several reasons not to use a small screwdriver to adjust the slugs.

First, it is all too easy to crack the slug since these are brittle and once broken will be jammed in the transformer core.

Second, the blades of screwdrivers are often magnetised and this can affect the magnetic characteristics of the slugs.

Third, when you are aligning the



radio, the steel blade of the screwdriver will affect the resonance of the coil and you will get misleading results.

You should use a set of plastic alignment tools (they're quite cheap) and use one which has a blade that's a neat fit in the slot of the slug.

If you can't purchase a suitable alignment tool, you can make one out of a piece of scrap plastic shaped at one end so that it is like a screwdriver blade and sized to neatly fit the slug slot. You can easily do this with a sharp utility knife and needle files. Many a plastic knitting needle has disappeared from mum's sewing basket over the years to make alignment tools!

When installing the ferrite rod antenna, secure the ferrite rod in place with cable ties but keep them loose for the moment, as you will need to adjust the coil position later during alignment.

The coil on the ferrite rod has four very fine cotton-covered coloured wires. Keep these the length that they are, ie, do not cut them short, since they are already pre-tinned.

The circuit board connections for the antenna coil connections are labelled with the colours: clear (CLR), black (BLK), red (RED) and green (GRN). The clear wire is the one that is at the far end of the coil and is separate from the remaining three wires.

The plastic dielectric tuning capacitor (or tuning "gang") is normally supplied with two tiny M3 screws which are used to secure it to the PCB. After these are inserted and tightened, the three tags need to be bent at right angles to insert into the holes on the PCB. They are then soldered in place.

You'll need a hacksaw to cut the volume control potentiometer shaft to 17mm in length (from where the threaded boss starts). There is a small location spigot on the side of the pot, which is not needed, so it can be snapped off with a pair of pliers or cut off with sidecutters.

We want to solder the pot body to the PC stakes to hold it securely in place but the body is normally "passivated" to prevent corrosion. This makes it almost impossible to solder – so you will need to scrape the pot sides with a hobby knife to remove some of the passivation before soldering.

Pass the potentiometer through the PCB from the component side and secure it with its washer and nut on the "top" or label side. Bend the tags so that they touch the PC stakes on the board and solder them in place.

Trimpot VR2, for the audio amplifier output biasing, can also be installed at this stage, followed by the battery holder, on/off switch and headphone socket. The battery holder is held in place with self-tapping screws. The power switch and headphone socket are mounted directly on the board.

Speaker mounting

The speaker is fastened directly to the PCB using four M3 screws and nuts, with short lengths of hookup wire between the loudspeaker and speaker PC stakes.

Note that there are eight speaker mounting holes, two sets of four on two different circumferences. So select the correct holes for your particular loudspeaker and orient it so the terminals are nearest to CON2.

Now check all your work very carefully and you will be ready for the next stage which is alignment.

Aligning your radio

The major difference between this project and any other that you may build is the need for alignment. Even if you have assembled the radio precisely as we have described so far, there is little chance that it will work satisfactorily when you first turn it on.

This is because even tiny variations in component values and characteristics and even slightly different PCB track widths and fibreglass thickness can cause frequency shifts which throw the workings of the radio off.

There are various adjustments to compensate for this, including the adjustment slugs in the IF transformers, which need to be "tweaked" to give the best gain and frequency response.

You will also need to adjust the slug in the oscillator coil and the trimmer capacitors associated with the tuning gang to give the best tracking. The reso-

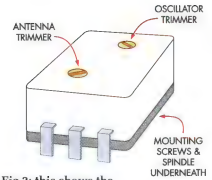


Fig.3: this shows the locations of the antenna and oscillator trimmer adjustments on the tuning gang.

nant circuit of the oscillator (T2, VC3 and VC4) must track with the aerial resonant circuit (T1, VC1 and VC2) across the whole of the broadcast band.

Otherwise, the set's sensitivity will vary quite markedly as you tune it. This also helps to ensure that stations appear at their correct locations on the tuning dial.

Before you start the alignment process, rotate trimpot VR2 fully anticlockwise. This will reduce the quiescent current in the output stage transistors, Q6 and Q7, to zero. Rotate the volume control pot and the tuning knob fully anticlockwise too.

This done, connect a 9V battery or 9V DC power source (a 9V DC plugpack or 9V power supply – but make sure the centre pin is positive) and then measure voltages around the circuit. Connect the negative probe of your multimeter to the GND test point and then verify that the following voltages are correct:

TP+ (8.88V), TP1(1.55V), TP2 (8.88V), TP3 (1.1V), TP4 (8.88V), TP5 (1.78V), TP6 (9V), TP7 (4.7V), TP8 (4.3V), TP9 (3.73V), TP10 (4.2V).

In each case, the voltage should be within about 10% of the value noted above assuming that the supply is exactly 9V. If the voltages are quite different from the values listed above, then you should investigate why. For example, if your supply is actually putting out 9.5V then the readings which are supposed to be 8.88V could easily be 9.38V instead (and TP6 will be 9.5V).

By the way, these voltages are 'no signal' voltages. That means little or no signal should be picked up by the input stage and the volume control is turned down so that there is no signal going through the amplifier stages. The presence of signals will alter these voltages, although not greatly.

You can also measure the current drain now. This can be done by connecting your multimeter (selected for measuring a low current range) across the on/off switch between the centre and rear terminals at one side of the switch. Alternatively, connect the multimeter between the anode of diode D3 and the 9V battery positive terminal.

With the switch set switched off, the current through the meter should be less than 10mA. We measured 3mA on our prototype. If you measure a lot more (more than 10mA) or a lot less (under 1mA), disconnect the multimeter and check the board carefully for assembly errors, solder bridges, etc.

Aligning the IF stages involves injecting a 455kHz signal into the front end of the circuit. As mentioned, earlier, the DDS IF Alignment unit from September 2017 makes this easy. See the side panel on how to do this.

The alternative is to connect an RF oscillator, set to 455kHz, through a 1nF ceramic capacitor to test point TP1. If you don't have an RF oscillator, you could use an audio signal generator set to produce a square wave at 152kHz with an 800mV output level. Since a square wave produces odd order harmonics, it is the third harmonic (3 x 152kHz) from the square wave at 456kHz that will be your signal for the IF alignment.

Connect your multimeter (set to read DC volts) between test point TP3 and ground. Set the RF generator to give a signal output of about 1mV RMS or the audio signal generator square wave to 800mV RMS. The idea is to now adjust each of the slugs in the IF transformers in turn for a minimum voltage on test point TP3.

As you adjust the slugs, the gain of the IF stages improves and the signal fed to the detector diode (D1) increases. The detector diode rectifies the IF signal and so, as the signal increases, the negative voltage produced by the detector increases. Hence, the voltage at test point TP3 decreases.

Note that after adjusting all the slugs, you may wish to go back through them again and check that they are all set at their optimum position. It's sometimes possible to make improvements the second time around that were hard to see initially.

Oscilloscope method

If you have access to an oscilloscope, you can connect it to TP6 and observe the IF signal directly.

Now, as you adjust the slugs, you will see the signal increase or decrease. Adjust the slugs for the best possible (ie, highest) signal amplitude.

If you notice any clipping of the signal at TP6, just reduce the signal input from your RF oscillator.

Tracking adjustments

These adjustments ensure that the

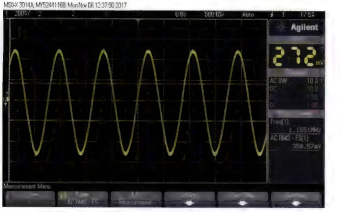
Resistor Colour Codes

Qty	Value	4-Band Code (1%)	5-Band Code (1%)
1	1.2MΩ*	brown red green brown	brown red black yellow brown
1	1MΩ	brown black green brown	brown black black yellow brown
1	820kΩ	grey red yellow brown	grey red black orange brown
1	47kΩ	yellow purple orange brown	yellow purple black red brown
1	39kΩ	orange white orange brown	orange white black red brown
1	27kΩ	red purple orange brown	red purple black red brown
1	22kΩ	red red orange brown	red red black red brown
1	12kΩ	brown red orange brown	brown red black red brown
1	10kΩ	brown black orange brown	brown black red brown
1	4.7kΩ	yellow purple red brown	yellow purple black brown brown
2	3.3kΩ	orange orange red brown	orange orange black brown brown
1	2.2kΩ	red red red brown	red red black brown brown
2	1kΩ	brown black red brown	brown black black brown brown
1	470Ω	yellow purple brown brown	yellow purple black black brown
1	100Ω	brown black brown brown	brown black black black brown

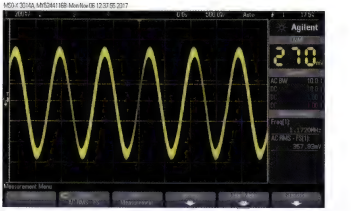
* 1.2MΩ 5% carbon can be used: its colour code will be brown red green gold

Small Capacitor Codes

Qty	Value/Type	EIA	IEC
3	100nF ceramic	104	100n
1	47nF polyester	473	47n
4	22nF polyester	223	22n
1	10nF polyester	103	10n
1	4.7nF polyester	472	4n7



Scope1: voltage at the collector of Q1 with the set tuned to around 700kHz 700kHz + 455kHz = 1.155MHz). You can see that the oscillator waveform is a clean sinewave with an amplitude of around 350mV RMS.



Scope2: now a test signal has been coupled into the ferrite rod. The test signal was modulated onto a 720kHz carrier. You can see the effect of signal modulation in the thickening of the trace away from the centre.

RF input circuit and the local oscillator cover the correct range of frequencies so that you can tune over the entire broadcast band. Ideally, you need an RF signal generator to do this task. If you don't have access to one, you will have to rely on tuning stations at the top and bottom of the band.

In Australia, the broadcast band is specified as 531-1602kHz, so to be sure you are covering this band, it is normal to make a radio tune over a slightly wide range, eg, 525-1620kHz.

If you are in an area where there are "out of band" AM stations, such as narrowcasting community stations up to about 1711kHz, you need to make the receiver tune slightly higher again. (See **www.acma.gov.au/theACMA/narrowband-area-service-licensing**).

Let's first proceed on the basis that you have an RF signal generator. If you don't have an RF signal generator, see the section entitled "Setting the tuning range without an RF generator".

With signal applied to TP1 via a 1nF capacitor, set the generator to 525kHz and rotate the tuning knob fully anticlockwise. This sets the plates of the tuning gang "in mesh" which is the maximum capacitance condition, for the low-frequency end of the band. Now adjust the slug in the oscillator coil for maximum loudness of the signal via the speaker, or (if you are using an oscilloscope) for maximum signal amplitude at TP6.

Next, rotate the tuning knob so that it is fully clockwise. Set your RF signal generator to 1620kHz. Tune the adjustment screw on the back of the tuning gang labelled "oscillator trimmer" (see Fig.3) for maximum signal amplitude, as before. Rotate the tuning knob fully anticlockwise and redo the oscillator coil slug adjustment again at 525kHz.

This done, go back to the top of the band at 1620kHz and adjust the oscillator trimmer again. The adjustments need to be done a number of times as the top adjustment affects the bottom adjustment and vice versa.

You have now adjusted the oscillator range so that the broadcast band can be tuned in and this also ensures that the stations are tuned in at the locations indicated on the dial.

As a point of interest, the oscillator will now be tuned over the range 980-2075kHz. That's 525kHz plus the IF of 455kHz to 1620kHz plus 455kHz.

Now you need to adjust the ferrite rod coil and antenna trimmer (on the back of the tuning gang) to maximise sensitivity by ensuring the aerial circuit is resonant at the tuned frequency. Set the tuning knob fully anticlockwise and set the RF signal generator to 525kHz, then move the coil along on the ferrite rod until the signal amplitude is at a peak.

You may have to (carefully!) heat up the coil with a hot air gun to melt the wax between the coil and ferrite rod, before the coil can be moved.

Setting the tuning range without an RF generator

In the accompanying procedure for setting oscillator and antenna tracking, we assumed that you had access to an RF signal generator. For many constructors, this won't be the case and they will have to rely on broadcast signals at the top and bottom of the broadcast band.

However, this poses something of a 'chicken & egg' situation. How do you do the tracking adjustments if you cannot receive the signals? In most cases, you should be able to receive signals at or near the bottom of the broadcast band especially at night (typically high power ABC radio stations). For example, in Sydney, you can tune in to ABC Radio National at 576kHz.

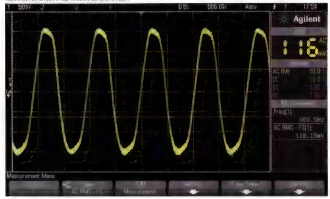
However, picking up a signal at the top end of the band might not be anywhere as easy. The highest frequency nationwide AM radio station is In Sydney, the highest commercial AM station is at 1269kHz (2SM). Above that, there are only community and narrowcast radio stations which may not be strong enough to use for this purpose in all areas of the city.

But there is a solution if you have another AM Radio since every superhet has a local oscillator and for an AM broadcast receiver, this oscillator will usually be 455kHz above the tuned frequency. Therefore, you can use the local oscillator in your other AM radio to set the tracking adjustments at the top of the band.

The method to follow is this: place the ferrite rod of the Super-7 AM Radio near the antenna rod other AM radio. This rod will usually be at the top of the case. Rotate the tuning dial of the Super-7 AM Radio fully clockwise to tune to the top of the band. Tune your other AM radio to 1165kHz or as close to this as you can. This will set its local oscillator to 1620kHz. That's the top of the band on the Super-7 AM Radio's dial.

As you do so, you should be able to hear faint heterodyne whistles from the speaker of the AM radio. Now proceed to peak the antenna and oscillator circuits as described in the article.

Scope3: waveform across the speaker with VR1 at its minimum setting and a ~1kHz modulated RF test signal inductively coupled into the antenna. The zero crossing artefacts are quite severe with no quiescent current.



Scope4: the audio output sounded very raspy when capturing Scope3. We then rotated VR1 clockwise until the sound became much cleaner and took the screen grab shown here. The signal looks much more like a sinewave.

Now set the RF generator to 1620kHz and turn the adjustment screw on the back of the tuning gang labelled "antenna trimmer" (see Fig.3) until you peak the incoming signal again.

You should now repeat these adjustments for the optimum response. When this is done, the ferrite rod coil should be fixed in place by re-melting the wax and allowing it to set. That completes the alignment of the radio.

Quiescent current

All that remains to be done is to set the quiescent current in the audio power amplifier by means of trimpot VR2. The best way to adjust the quiescent current is to feed a sinewave modulated signal into the front end of the radio from an RF signal generator.

Connect an oscilloscope to the output at test point TP10 and adjust the volume control for a signal amplitude across the speaker of about 2-3V peak-to-peak. At this stage, VR2 should still be fully anticlockwise. If you now have a look at the signal on the scope screen, you will see the classic sinewave with crossover distortion with notches in the waveform at the crossover point (see Scope3).

Now rotate VR2 slowly clockwise and you should see the crossover nicks disappear from the waveform and, at the same time, the sound should become cleaner.

Rotating VR2 to reduce the crossover distortion will not increase the current drain by much (typically no more than a milliamp) but it will make a big difference to the sound quality.

No 'scope?

If you don't have an oscilloscope, you can apply a signal at 1kHz from an audio generator (100mV is suitable) to the centre of VR1, with VR1 set to mid position. This will apply audio directly to the amplifier.

Adjust VR2 for minimum distortion either by listening to the sound (it should become "pure" with adjustment) or by monitoring on an oscilloscope.

By the way, you should measure the current drain of the radio while you are adjusting the quiescent current with trimpot VR2.

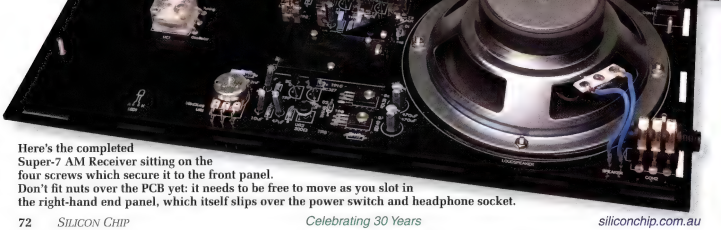
Typically, the current drain of the radio at 9V should be less than 10mA when the volume control is at minimum setting (ie, no signal through the audio amplifier stages).

With the volume control well advanced, to make the radio quite loud, the current drain may be 40mA or more.

Don't rotate VR2 any more than necessary as this will increase dissipation in the output transistors and will flatten the battery faster when listening.

If in doubt, back it off a bit (rotate it anti-clockwise) until you hear an increase in distortion, then rotate it a tiny bit clockwise until that distortion is gone and you are near the ideal setting.

Note that using the radio with high



Here's the completed Super-7 AM Receiver sitting on the four screws which secure it to the front panel. Don't fit nuts over the PCB yet: it needs to be free to move as you slot in the right-hand end panel, which itself slips over the power switch and headphone socket.

volume will flatten the battery much more quickly than at low volume . . .

The acrylic case

Because it is self-contained (ie, fully on one PCB) the Super-7 AM radio would be quite happy working without a case. But if you want a really professional finish, you'll want to put it into the purpose-designed acrylic case. Its appearance is not unlike the mantel radios of yesterday . . .only it is shiny black!

The case measures 327 x 155 x 58mm (w x h x d) and the front, sides, top and bottom are made from a very smart high-gloss black. The back panel is transparent so everyone can admire your handywork!

Provision is made in the left end panel for the on-off switch, a DC power plug and the 6.5mm headphone socket.

On the front panel, attractive slots are milled for sound output immediately in front of the speaker and at the right end there's a matching 105mm hole for the clear acrylic tuning "dial" which reveals the screen-printed PCB underneath with its major radio stations.

While you can easily move the tuning dial with your fingers, we gilded the lily somewhat by gluing a large knob to the centre of the dial (a knob makes it easier to find elusive stations!) – whether you add a knob is entirely up to you. Immediately underneath and to the left of the tuning dial is the single "volume" control

The case simply slots together and everything is held in place by four 50mm long pillars which go from front to back – more on these shortly.

We've also made provision on the bottom front of the case for a pair of rubber feet which can angle the whole receiver back slightly. Again, this is entirely optional.

Putting the case together

Remove the nuts from the volume control pot and headphone socket, if fitted. It doesn't matter if the clear acrylic "dial" is fitted to the tuning capacitor; it can be done now or later.

Start with the front panel. Insert four M3 x 15mm screws through the four holes near the edges and put a washer and nut on each to hold them in place. Now slide the receiver PCB down over these screws, obviously oriented so the speaker sits behind the slots and the dial markings behind the 105mm hole.

Slide the left end panel into its slots on the front panel, at the same time engaging the on/off switch shaft and the 6.5mm headphone socket. You will probably have to lift the PCB on this end to allow this.

When in position, refit the nut onto the headphone socket – this will hold the end panel in place.

Now you can slide the bottom, top and right end panels into place, with their tabs fitted into the slots on the front panel and each other.

Threaded standoffs

It's not easy (impossible?) to buy a threaded standoff long enough (45mm+) to hold the rear panel onto the front panel. If you can find (or make!) a 45mm M3 threaded standoff, more power to you!

We made ours with a combination of 15mm and a 25mm M3 threaded standoffs, M3 studs to join them into single 40mm lengths, plus a few M3 nuts and washers to end up with the 50mm length required.

The "stud" which joins the 15 and 25mm lengths was simply a short (15mm) M3 screw with its head cut off with a hacksaw. (You will probably need to run a nut over the cut-off section to reform the thread).

Two M3 nuts were used between the two standoffs as spacers. Fig.4 shows this a little more clearly. The overall length of the standoff, top of PCB to bottom of rear panel, is 50mm. Given that nuts vary all over the place in height, simply choose the number of nuts and/or washers to make your standoffs 50mm long.

We made four of these. The bottom ends screw onto the M3 screws which pass through the case front panel (with a nut) and then the PCB. The top ends fasten to the four M3 screws which hold the rear panel in place.

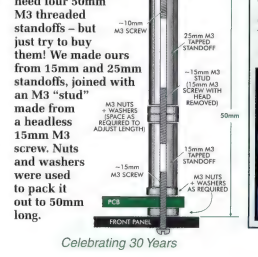


Fig.4: you need four 50mm M3 threaded standoffs – but just try to buy them! We made ours from 15mm and 25mm standoffs, joined with an M3 "stud" made from a headless 15mm M3 screw. Nuts and washers were used to pack it out to 50mm long.

Using the DDS Superhet Alignment Unit (Sept 17)

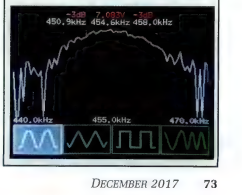
The DDS IF Alignment unit makes aligning the Super-7 quite straightforward. While its IF alignment mode is handy for verifying the alignment is correct, the AM modulated signal generator is actually the mode we used the most during alignment.

The DDS module allows you to generate the 455kHz, 525kHz and 1620kHz test signals with or without modulation. Simply enter the required frequency and select sinewave mode.

We simply produced a maximum (or near maximum) amplitude signal and fed it to a small wire loop which we placed near the ferrite rod. However, you could also use the onboard attenuator to produce a lower level signal suitable for direct injection via a 1nF capacitor, as per the main text.

Note that we found proper alignment much easier with the aid of a scope since this allows you to see how cleanly the modulated test signal is being demodulated and you can tweak the alignment to give not only the strongest but also least distorted signal output.

Once you've completed the alignment procedure as stated in the main text, you can then set the generator frequency and switch to IF alignment mode to verify that the IF bandwidth peaks around 455kHz and has the correct ~10kHz bandwidth to the -3dB points, as shown in the screen photo below.



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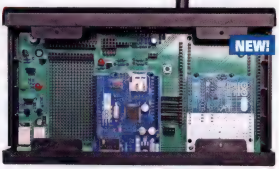

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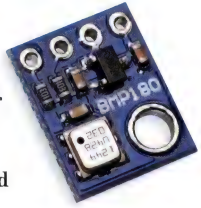
Elecrow GY-68 & GY-BM Barometer/Temperature Sensor Modules

This month, we're looking at two very tiny modules which sense barometric pressure and air temperature. One uses the Bosch BMP180 digital pressure sensor, while the other uses the newer BMP280 sensor. Both can send their readings to virtually any micro via a standard I²C serial interface, while the BMP280-based module also offers an SPI interface.



The first thing you notice about the Elecrow GY-68 digital barometer module is its tiny physical size. It measures only 13 x 10 x 2.5mm, making it by far the smallest module we've looked at so far in these articles. The BMP180 sensor IC which forms the functional heart of the module is much smaller again, measuring only 3.6 x 3.8 x 0.93mm.

The BMP180 has what is described as ultra-low power consumption, drawing less than 10µA when taking readings once per second and less than 1µA in standby mode. Clearly, it's very suitable for use in compact portable devices like smartphones.

It's also a low-cost device. The Elecrow GY-68 module we're looking at here is available from the SILICON CHIP online shop for just $5 plus postage (catalog code SC4343).

The BMP180 sensor

This is made by Bosch Sensortec, a division of the large German firm Robert Bosch GmbH (**www.boschsensortec.com**). The BMP180 is based on piezo-resistive MEMS technology, where MEMS stands for "MicroElectroMechanical Systems".

In other words, it uses a tiny sensor element which flexes mechanically in response to changes in atmospheric pressure and the flexing is sensed by measuring changes in the element's resistance.

The BMP180's 3.6 x 3.8 x 0.93mm metal package has a tiny vent hole (about 0.5mm diameter) in the top to allow the sensor element access to the outside air. And apart from the sensor element, there are three other functional blocks inside the device.

As shown in Fig.1, the three blocks comprise an ADC (analog to digital converter) to make the measurements, a control unit which also provides the I²C serial interface for communicating with an external micro and an EEPROM which has 22 bytes of storage for the device's 11 x 16-bit calibration parameters.

Every individual BMP180 device is calibrated during manufacture, after which the calibration parameters are saved in its EEPROM. An external micro can read these parameters and use them to correct that sensor's readings for offset, temperature dependence and other factors.

So with suitable software, the BMP180 can provide very high accuracy measurements of both barometric pressure and temperature. The relative accuracy for pressure is quoted as ±0.12hPa from 950-1050hPa at 25°C, while the absolute accuracy is quoted as -4 to +2hPa over the range from 300-1100hPa and for temperatures of 0-65°C. Impressive!

With the right software, it's also fairly easy to use the BMP180 as an altimeter, capable of indicating your current altitude above mean sea level (MSL). So its applications are not limited to being used as a barometer and thermometer.

By the way, although the BMP180 normally comes with the I²C serial interface, a variant is also available with an SPI interface. Presumably, this would be for large orders from equipment manufacturers.

By the way, if you're unfamiliar with barometers and the various units used for atmospheric or barometric pressure, you might like to refer to the panel headed "Barometric Pressure and Units".

Elecrow's GY-68 module

As you can see from the photo of the Elecrow module, there are few components apart from the BMP180 sensor itself: just an SOT-23 low-dropout (LDO) voltage regulator, three surface-mount capacitors and two resistors.

Fig.2 shows its complete circuit. REG1 is the MCP1700 3.3V LDO regulator, used to ensure that the supply voltage for the BMP180 is kept within

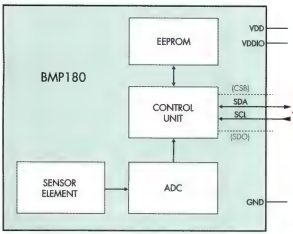


Fig.1: block diagram of the BMP180 (the small metal package located on the module). It contains 22 bytes of EEPROM for storing calibration values.

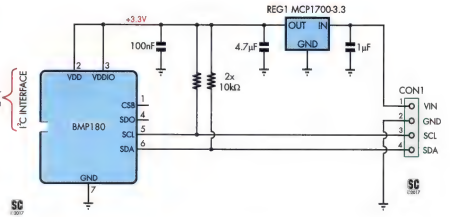


Fig.2: complete circuit for the GY-68 module. CON1 provides power and I²C interfacing for the module, which draws less than 10µA when taking readings, and 1µA in standby mode.

its ratings (3.6V max). It also ensures that the two pull-up resistors on the I²C interface's SDA and SCL are returned to the same safe voltage level. The three capacitors are for supply rail bypassing.

CON1 is the 4-pin connector used both to supply the module with its power and also to connect to an external micro via the I²C interface. Since the module draws less than 10µA from the supply when it's taking one measurement per second, there's no problem in powering it from an Arduino or a Micromite module or from a power bank using a 3.7V Li-ion cell.

Connecting it to a micro

Fig.3 shows a simple way of connecting the GY-68 barometer module to an Arduino. The SCL and SDA lines of the GY-68 connect to the SCL/A5 and SDA/A4 pins of the Arduino, while the V_{IN} and GND lines connect to the +5V and GND pins respectively. That's all there is to it.

It's equally simple to connect the module to a Micromite, as you can see from Fig.4. Here the SCL and SDA lines connect to pins 17 and 18 of the Micromite respectively, while as before, the V_{IN} and GND lines go to +5V and GND.

Programming it

It's relatively easy to get the GY-68 module working happily with an Arduino, although this does involve the use of a matching software library called SFE_BMP18.zip. This can be downloaded from the Elecrow website at **www.elecrow.com.wiki/index.php?title=File:SFE_BMP180.zip**

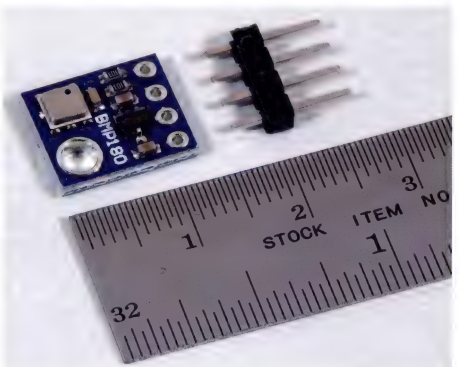
After downloading, it can be added to the libraries in your Arduino IDE by clicking on Sketch → Include Library → Add .ZIP Library and then directing it to the folder into which the zip file was downloaded.

On the SILICON CHIP website, you can find a small sketch for running the GY-68/BMP180 with an Arduino, called "SFE_BMP180_barometer_sketch.ino". I have adapted it from a sample sketch provided by Elecrow.

It's pretty straightforward, first initialising the BMP180 (ie, extracting the calibration parameters from its EEPROM) and then taking a measurement of temperature and barometric pressure every five seconds.

Each time it takes a measurement, it crunches the data and displays the results on the Arduino IDE's Serial Monitor. A sample of this is shown in the screen grab of Fig.5.

Since the BMP180 only measures the temperature and absolute air pressure, the sketch needs to know your current altitude above sea level in order to calculate the corresponding MSL pressure.



The Elecrow GY-68 module is shown here at three times actual size, as it is only 13 x 10mm. The metal package BMP180 sensor (3.6 x 3.8mm) is based on piezo-resistive MEMS technology.

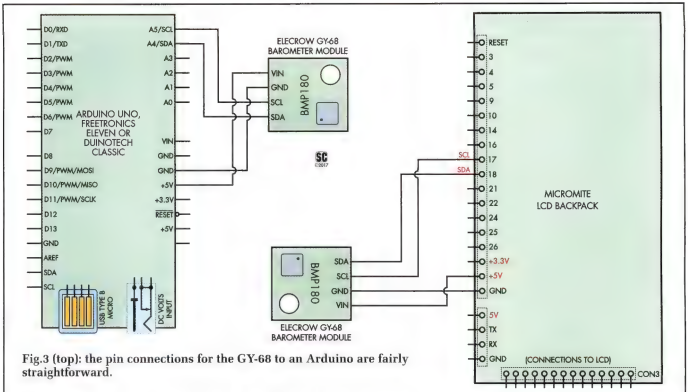


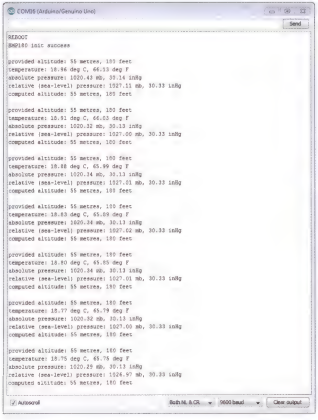
Fig.3 (top): the pin connections for the GY-68 to an Arduino are fairly straightforward.

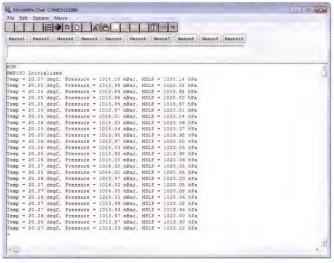
Fig.4 (upper right): pin connections for the GY-68 to a Micromite module.

Fig.5 (bottom left): example data from the GY-68 sensor module when connected to an Arduino.

Fig.6 (right): example data from the module when connected to a Micromite.

Fig.7 (bottom right): when running the Micromite sample software, if there is a screen attached, it will also show the readings on the display.





This information is fed to it in this line, located very close to the start of the sketch:

```
#define ALTITUDE 55.0
```

This sets the altitude to 55 metres, which is a rough estimate of my workbench's altitude above MSL. However, as the comment on the right of this line explains, you can easily substitute your own altitude if you want maximum accuracy.

You'll note from Fig.5 that the sketch repeats this altitude figure in the first line of each set of measurements, giving it in both metres and feet. It also shows the temperature reading in both degrees Celsius and degrees Fahrenheit as well as the absolute and MSL-relative pressures in both millibars and inHg (inch of mercury; reflecting its origin in the USA).

Finally, it repeats the altitude figures again, but this time describes them as "computed altitude". This sketch is a good way to see what the GY-68 module can do.

It's not quite so easy to get the GY-68 module working with a Micromite because there is no pre-existing or built-in library designed to communicate with it and do the calculations to provide the corrected temperature and pressures.

However, I have written an MMBasic program to do the job and you can download it ("BMP180 barometer check prog.bas") from the SILICON CHIP website.

This program expects a GY-68/BMP180 to be connected to the Micromite as shown in Fig.4 so once you do this and upload the program, it should spring into life.

If you have the Micromite still connected to your PC and have Micromite Chat open, you'll see that it produces temperature and pressure measurements every second, as shown in the screen grab of Fig.6.

Just as with the Arduino sketch, this program also needs to know your current altitude/elevation in order to work out the equivalent barometric pressure at MSL.

As before, you need to substitute your elevation in this line, which you'll find near the start of the program and in about the middle of the declaration of the program's variables:

```
DIM AS INTEGER Alt = 50
```

Simply substitute your own altitude/elevation above MSL (in metres) instead of the "50" in this line, then upload the program to the Micromite and get it going (by clicking on the little "gearwheel" button in the Micromite Chat toolbar). It will then show the current mean-sea-level pressure (MSLP) as the last item in each line.

If your Micromite is hooked up to an LCD touchscreen, it will also give you an on-screen display of the temperature and pressure readings as shown in the screen shot of Fig.7. Like the measurements sent back to your PC, the display is updated every second.

Incidentally, I compared the temperature and pressure readings achieved using this program with the figures shown on the Australian Government Bureau of Meteorology website (which updates every 10 minutes in the Sydney area), and they compared surprisingly well. The temperature was within 0.2°C and the MSL pressure within 0.5hPa; not bad at all for such a small device!

If you want to make your own comparisons, you'll find the Bureau of Meteorology website at **www.bom.gov.au**

You just have to select your state, then Observations, then select your area in the state.

Barometric Pressure and Units

You'll find quite a few units in use for measuring atmospheric or barometric pressure: Pascals (Pa) and hectoPascals (hPa), bars (B) and millibars (mB), millimetres of Mercury (mmHg) and inches of Mercury (inHg).

Basically, atmospheric pressure is due to the weight of air immediately above you and it corresponds to a force per unit area. The primary SI unit for pressure is the Pascal (Pa), which is equivalent to a force of 1 Newton per square metre. That is, 1Pa = 1N/m^2.

It turns out that a column of air one square centimetre in cross section, measured from sea level to the top of the Earth's atmosphere, has a mass of about 1.03kg and a weight of 10.1325N. This corresponds to a pressure of 101,132N/m^2, or 101,325Pa (= 101.325kPa = 1013.25hPa, since 1hPa = 100Pa). So the standard atmosphere is defined as 101,325Pa or 1013.25hPa.

The actual barometric pressure at any particular location depends upon its elevation or altitude with respect to mean sea level (MSL), because the higher the elevation, the lower the weight of air directly above you and the lower the pressure.

For low altitudes, it can be estimated as falling by about 10hPa for every 100m rise above MSL. For higher altitudes, the pressure at any elevation/altitude can be found by a standard expression known as the Barometric Formula.

The first barometers (invented in 1643 by Italian physicist Evangelista Torricelli) used to measure atmospheric pressure used a column of mercury in a vertical glass tube and as a result, they were calibrated in terms of the height of the mercury column, measured in either millimetres or inches. So that's where the "mmHg" and "inHg" units of pressure came from.

In fact, "inHg" is still used in the United States, Canada and Colombia. For the record, one standard atmosphere of 1013.25hPa is equivalent to 760mmHg or 29.92inHg.

So where do the bar and the millibar units fit in? Well, the bar was a unit of weight used in the metric system before about 1800. Then around 1890, it was used as a unit of atmospheric pressure by Norwegian physicist and pioneering meteorologist Vilhelm Bjerknes. Since then, it has been used sporadically as a unit of atmospheric pressure, although nowadays it is frowned upon and not regarded as part of the SI system of metric units.

For the record, 1 bar is regarded as equal to 100kPa or 1000hPa and 1mbar equal to 1hPa or 100Pa. Thus, a standard atmosphere corresponds to 1013.25mbar or 1.01325bar. For more information, see **https://en.wikipedia.org/wiki/Atmospheric_pressure**

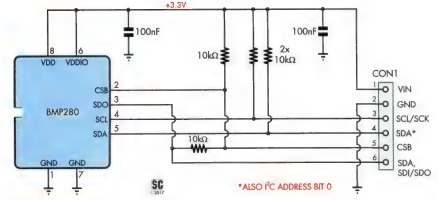


Fig.8: complete circuit diagram for the GY-BM module. Compared to the GY-68's circuit shown in Fig.2, this device is quite a bit simpler in design, removing the need for an external regulator.

You'll then see a list of observation stations in that area and then when you click on a station near you, you'll see a list of the weather data for that day, including temperature and MSLP.

The new GY-BM module

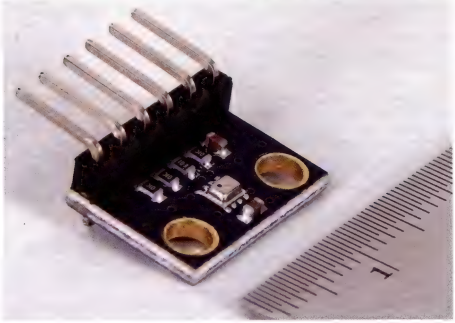
Elecrow have recently added a second digital Barometer/Temperature module to their range: the GY-BM module, based on Bosch Sensortec's new BMP280 digital sensor IC.

The new module is only slightly larger than the GY-68, but it is still very small – measuring only 15 x 11 x 3mm. On the other hand, the BMP280 sensor IC itself is even smaller than the BMP180, measuring only 2.0 x 2.5 x 0.95mm.

Despite this tiny size the BMP280 offers some advantages over the BMP180. These include a dual-mode SPI interface (modes "00" or "11") in addition to the I²C interface, higher measurement resolution for both pressure (0.16Pa vs 1Pa) and temperature (0.01°C vs 0.1°C), lower current consumption (2.7μA vs 12μA) and an internal software configurable IIR filter to allow minimisation of short-term air pressure disturbances.

In terms of absolute accuracy, the BMP280 is essentially identical to the BMP180. Pressure accuracy is ±1hPa from 0-65°C, while the temperature accuracy is ±0.5°C at 25°C and ±1.0°C from 0-65°C.

The internals of the BMP280 appear to be very similar to those of the BMP180 shown in Fig.1, apart from it being provided with an SPI interface as well as the I²C interface. The calibration parameters are again stored in a 22-byte internal EEPROM/NVM (non-volatile memory) during manufacture.



The new GY-BM module is a tad larger than the previous GY-68 model and the BMP280 has near identical performance to the BMP180.

The GY-BM module shown above, close to actual size.

The circuit of the GY-BM module is shown in Fig.8, and as you can see it's even simpler than that of the GY-68 module shown in Fig.2. That is because the GY-BM module is intended to run only from a nominal 3.3V supply, and as a result it has no on-board LDO (low dropout) regulator.

On the other hand, it has a six-pin connector (CON1) compared to the four pins of the GY-68. The two extra pins are required because the optional SPI interface requires four pins, compared to just two for the I²C interface.

To connect the GY-BM module to a micro using the I²C interface, the SDA line should be connected to pin 6 of CON1, while the SCL line is connected to pin 3.

Additionally, the CSB pin (CON1 pin 5) should be left floating, so it's pulled high via the 10kΩ pullup resistor – this signals to the BMP280 that the I²C interface is to be used.

Finally, pin 4 of CON1 can be used to set the module's I²C address, connecting it to ground to give it the same "default" address as the BMP180, or connecting it to V_{IN} (+3.3V) to give it a different address.

However, if you want to connect the GY-BM module to a micro using a standard four-wire SPI interface, the SDI line should be connected to pin 6 of CON1, the SDO line to pin 4 of CON1, the SCK line to pin 3 of CON1 and finally the CSB (Chip Select-bar) line to pin 5 of CON1.

The GY-BM module should be just as easy to use as the GY-68 module. Just make sure that you connect its supply input V_{IN} (CON1 pin 1) to +3.3V, not the +5V supply used for the GY-68 module. Otherwise the BMP280 chip may be irrevocably damaged. SC

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6GHz+ Touchscreen Frequency and Period Counter

Having described our new 6GHz+ Touchscreen Frequency/Period Counter in the first article (October) and then built and tested it (November), we shall now show how to use it and explain what it can do. Apart from its very wide frequency range, it offers outstanding accuracy.

Part 3: by Nicholas Vinen

Assuming you've managed to source the components for the Frequency Meter (most of which are available from either the SILICON CHIP Online Shop or Digi-Key) and successfully put it together, you can then program the Explore 100 with the software.

We don't supply the PIC32 pre-programmed with the BASIC code because the Explore 100 provides a USB interface that makes loading it quite easy.

The PIC32 which is supplied in our Explore 100 kit (or the one from Rictech in New Zealand) does already have the MMBasic firmware loaded. So you just need to connect it to your PC, download the software from our website (free for subscribers) and load it into the Micromite Plus chip.

The procedures for doing that, as well as setting up the LCD touchscreen, were given in last month's article.

Assuming that all went well, your unit should be operational. The rest of this article explains how to use the software and its touchscreen interface.

Main screen display

Pretty much all the functions of the Frequency Counter are available on the one main screen, shown in Fig.5. This is similar to the prototype screen shown in the last two articles but with a few small tweaks as the software has been finalised.

There is information shown in each corner of the screen, plus the large frequency/period display in the centre. The frequency/period is auto-ranging with frequency using units of mHz (millihertz, ie, 1/1000th of one hertz), Hz, kHz, MHz or GHz and period having units of ps, ns, µs, ms or s.

You can switch between frequency and period display by touching the centre of the screen.

Changing between frequency and period display does not affect the way the measurement is being taken; both readings are calculated based on the number of pulses received from the reference clock and the input signal in a given period.

The frequency is simply calculated as F_{in}/F_{ref} while the period is F_{ref}/F_{in}.

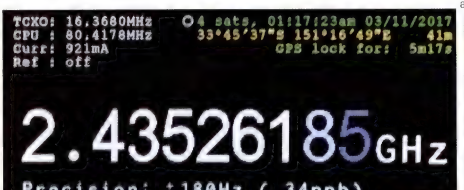

Fig.5: the default main screen, showing the frequency reading in large digits at the centre and various additional information below that, and in the corners of the display. To change the settings in the corners, it's generally just a matter of touching that area of the screen.

Note that all settings, including this one, are retained in Flash memory automatically so that the configuration is retained for the next time the unit is powered up.

Accuracy and precision estimate display

Regardless of what is being displayed, the precision and accuracy estimates are shown below. Precision indicates repeatability, ie, if you measured the same exact signal using the same settings on two different occasions, this is the maximum difference you could get between the two readings.

This relates to the stability of the reference oscillator and how its frequency changes over time and with temperature.

It's computed based on the reference clock tolerance and measurement period and shown as both the parts per million/billion error and a frequency or period uncertainty.

When using averaging, the uncertainty will drop over time until it reaches a minimum value, once the programmed averaging time period has passed.

The accuracy shown automatically improves quite dramatically if you're using GPS disciplining since this will allow the unit to compensate almost entirely for long-term drift (since GPS timekeeping is much more stable) and temperature drift will also be reduced (but not eliminated).

The accuracy figure is shown in a similar manner but this also takes into account the initial error in the reference oscillator frequency. This can be reduced if you have a more accurate reference source to calibrate the TXCO.

When using GPS disciplining, the accuracy figure will generally match the precision figure (or come close) since the accuracy provided by the GPS time signal is excellent.

Another indication of reading accuracy is the fact that the last couple of decimal places in the reading may be dimmed, indicating that they have a degree of uncertainty and even with a stable signal, you may see these digits fluctuate. If averaging is active then over time, the reading will become more certain and these digits will become lighter. With a stable signal, white digits should be quite stable.

Input switching

The current input is shown in the lower left-hand corner of the screen and you can switch inputs simply by touching it. Make sure you press far enough down the screen that you aren't pressing the Mode line above; changing mode will be explained shortly.

Mode switching is simple since it just toggles between the SMB (high frequency) input and the BNC (low frequency) input. If you're using averaging, it will reset when changing inputs.

The SMB input impedance is fixed at 50Ω but the BNC input impedance can be switched between 75Ω and about 1MΩ. This can be changed simply by touching that part of the Mode line when the BNC input is selected and like the other settings, it is retained even when power is lost.

Update rate and averaging

The range of update rates has been expanded to include one update every three, two or one second or five times per second. You can cycle through these update rates by touching the update line near the lower right-hand corner of the screen.

The update rate is independent of the averaging setting. Say you select 30s averaging with a 2s update rate. You will get a reading after two seconds but it will only be based on two seconds of data.

Then you will get a reading two seconds later which will be slightly more accurate (and the accuracy and precision figures will reflect this).

The time span over which the signal has averaged so far is shown in parentheses ( ) at the end of the Mode line.

The reading accuracy will continue to improve until the 30-second mark, at which point the precision and accuracy figures will not improve. The reading will continue to change though, representing the average signal frequency over a time "window" spanning the last 30 seconds.

In other words, the displayed value is a moving average.

If the signal frequency changes, you would have to wait 30 seconds for the new reading to be accurate. Alternatively, you can simply touch at the end of the Mode line, where the averaging time so far is displayed, to reset it to zero and start the averaging window anew.

To change the maximum window (ie, averaging) time, simply touch the left side of that line instead. This will cycle through a series of different time values from one second up to ten minutes.

To turn averaging off, you can keep pressing this until you get back to the "immediate" setting or alternative, to save time, hold your finger on the Mode line for a couple of seconds.

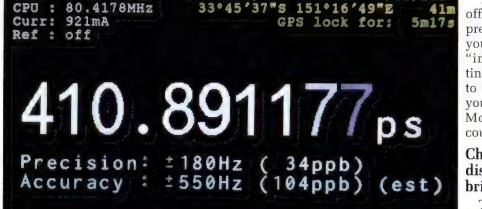

Fig.6: a similar display but this time with the output shown as a period rather than a frequency, and with averaging enabled. Most of the operation and interaction with the unit is done via this screen.

Changing the display brightness

To change the LCD backlight display brightness, press and hold your finger on the lower right-hand corner of the screen, where the current bright-

ness percentage is displayed. While still pressing on the screen, swipe your finger up or right to increase the brightness, or left or down to decrease the brightness.

Because you're starting in the lower-right corner, it's easiest to swipe up to increase and left to decrease. But if you swipe up and increase the brightness too much, you can go either down or left to bring it back to the desired value.

Reducing the brightness to the minimum will drop power consumption by around 200-250mA compared to maximum brightness. The estimated current drawn from the DC supply for a given configuration is shown in the upper-left corner of the screen.

Frequency reference calibration

The upper-left corner also shows the TCXO frequency and measured CPU (PIC32) operating frequency.

The latter is mainly for interest's sake. The CPU is typically operated at 80MHz as a compromise between screen update speed and power consumption/stability.

The PIC32 itself is perfectly stable at higher speeds but we saw some display glitches when driving the touchscreen at faster rates (the LCD bus speed is determined by the CPU clock rate).

The TCXO specified operates at a nominal 16.368MHz and this will be the default value at power-up. It can change for two reasons: either you've manually calibrated it (as described below) or the GPS 1PPS signal has been used to determine the actual TCXO frequency. So when GPS disciplining is available, the TCXO setting automatically updates when necessary.

These changes are saved to the PIC32's Flash memory so that the frequency can be accurate the next time the unit is powered up before it's been running long enough to get an accurate reading of the GPS time base.

For manual calibration (eg, if you have not fitted a GPS unit), you must first measure the TCXO frequency.

There are three ways to do this. The first is the simplest but needs to be done with the case open and requires an accurate frequency meter. It needs to be more accurate than the one you are calibrating, eg, around 1ppm or ±0.0001% accuracy or better.

Measure the frequency at pin 9 of the Explore 100 header, relative to pin 1 (ground). Then press on the TCXO frequency at upper-left and hold your finger down for a couple of seconds, then lift it.

A keypad will appear and you can enter the precise TCXO frequency in Hz.

It will then ask you for a second figure, the accuracy of your frequency meter, in ppb (parts per billion). 1ppm = 1000ppb = 0.0001%. This is used to provide the estimated precision and accuracy figures when making a measurement.

If you don't know, abort entering this number and the default value for an uncalibrated TCXO will be used, but the calibration itself will still be performed.

The new figures will be stored and displayed but you can recalibrate again at a later date if necessary.

The second option can be done with the case closed and all you need is an accurate frequency source. For example, you could use the 10MHz reference output from another piece of test equipment.

Make sure the TCXO frequency is set to the default value of 16.368MHz; if not, set it using the above procedure.

Feed the signal in and measure its frequency with reasonably long averaging (eg, one minute). Take note of the figure shown on the screen. Let's call it F_{meas} and the expected frequency F_{exact}. Now perform the following calculation, with all values in Hz:

TCXO =
16368000 x F_{exact} / F_{meas}

You can now program the resulting figure in as the new measured TCXO frequency using the procedure given above. If you know the accuracy of your reference signal frequency, enter that in when prompted for the "ppb" figure (in parts per billion).

The third method is a combination of the above two methods and requires a stable (but not necessarily accurate) frequency source along with an accurate frequency meter.

You simply measure the frequency of your signal source using the accurate meter, then feed that same signal into your newly built Frequency Meter and measure it as stated immediately above.

You can then perform the same calculation, using the figure you got from your known-accurate meter in place of F_{exact} and the figure from your new Meter as F_{meas}. As before, the accuracy (ppb) figure should reflect the accuracy of the meter you're using for calibration.

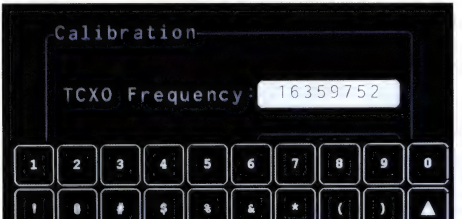

Fig.7: using the on-screen keypad to calibrate the onboard oscillator for greater accuracy. There are three different calibration methods given in the text, with the simplest involving measuring the oscillator frequency with a more accurate meter and then typing it in as shown here.

GPS disciplining

If you fit a GPS module, this is all pretty much automatic. The PIC32 should detect a valid serial stream from the GPS unit and display some figures in the upper-right corner of the screen. If not, check that you haven't transposed the TX and RX pins of the GPS unit or made some other mistake with the wiring. Check also that the power LED on your GPS unit is lit.

Most GPS units (including the

recommended VK2828) also has an LED which flashes when it has a good satellite lock.

If you're getting some indication in the upper-right corner that the GPS unit has been detected but you aren't seeing a proper fix (latitude, longitude, time, date, etc) then you may need to move the unit closer to a window or consider fitting a GPS module with an external antenna.

Note that it may take several minutes to get a lock even with a good signal, especially if the GPS module has not been used for many days.

Once a signal has been found, a circle is displayed which should flash at 1Hz, concurrent with the 1PPS signal from the GPS unit. It will be red if a satellite lock has not yet been achieved or green if it has.

Once it's green, the unit will start internally "time stamping" each pulse. If the lock remains good for at least a few minutes, the time stamps will be used to improve the TCXO frequency and thus the reading accuracy and precision.

The length of time that the unit has had a good satellite lock is shown below the latitude, longitude and altitude information (which are provided merely for your curiosity).

Also, it's important to realise that the time and date given are for UTC (GMT).

They're also provided for your reference; you need to know your current local time zone offset to convert them to local time.

By the way, we suggest once you get the Meter up and running, you leave it in a location with a good GPS signal lock and leave it powered up for at least half an hour to allow it to calibrate the TCXO frequency to a reasonable accuracy.

If you're only using it in short bursts later, it may not have enough time to get a good lock and so doing this periodically (eg, every couple of months) will help it continue to provide good accuracy.

SILICON CHIP 6GHz+ Touchscreen Frequency/Period Meter
Timestamp,Hz,Freq,PrecHz,AccHz,TCXO,Input,Imped,Mode,AvgSec,GPSSats,UTC,Date
6239317,5260135255,5.26013526GHz,240,370,16367993,SMB,50,1,5,124837,03112017
6239817,5260134170,5.26013417GHz,230,360,16367993,SMB,50,1,5,124837,03112017
6240317,5260134285,5.26013429GHz,220,350,16367993,SMB,50,1,5,124838,03112017
6240817,5260133925,5.26013393GHz,210,340,16367993,SMB,50,1,5,124838,03112017
6241317,5260133910,5.26013391GHz,200,330,16367993,SMB,50,1,5,124839,03112017
6241817,5260133965,5.26013397GHz,200,330,16367993,SMB,50,1,5,124839,03112017
6242317,5260133940,5.26013394GHz,195,325,16367993,SMB,50,1,5,124840,03112017
6242817,5260133995,5.26013400GHz,190,320,16367994,SMB,50,1,5,124840,03112017
6243317,5260133965,5.26013397GHz,190,320,16367994,SMB,50,1,5,124841,03112017

Table 1: sample output from the unit over the serial console, captured with a terminal emulator. The result is in a CSV format so you can save, plot and analyse it easily using standard software such as Microsoft Excel or LibreOffice/OpenOffice Calc.

Reference output

As stated in the earlier articles, the reference (BNC) output can produce one of three signals: a fixed 1Hz or 1kHz reference signal, or a frequency that is equal to the measured frequency divided by 1000 (for the BNC input) or 1,000,000 (for the SMB input).

This varying division ratio is necessary to keep the output frequency within reason at the upper end of the device's measurement range and is shown on-screen when you switch inputs. You still just need to substitute the units when reading the divided output to get the actual frequency.

Note that while the average frequency produced from the reference output should be very accurate, there could be some jitter because of the Pulse Diffusion technique used to provide an accurate division ratio. So it's best to feed it to equipment with a reasonably long acquisition window (say at least 100ms) to get good results.

Serial output

One feature we haven't mentioned so far is that the measured frequency/period, TCXO oscillator frequency and general configuration are also printed to the serial console in CSV format.

So if you want to hook the Meter up to your PC, you can do so and capture/log/process the resulting data quite easily.

You can see the output of the unit in MMEdit's "MMChat" window or you could use a serial console program like Tera Term Pro to view and capture this data. Set its baud rate to 115,200 and make sure the correct COM port is selected. Make sure to close MMEdit before launching Tera Term Pro so that the COM port isn't already in use. Once captured, save the data to a CSV file so you can open it later for analysis.

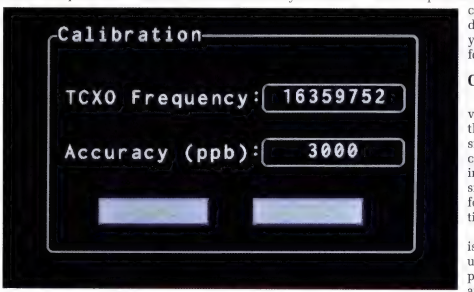

Fig.8: having entered the measured TCXO frequency, you also have the option of providing an accuracy figure to go along with it. This allows the unit to compute and display the new, better accuracy figure for any given reading. Press the Save button and the new calibration figures will take effect.

Conclusion

Despite all the previous explanation, this meter is quite simple to use, especially if you are using GPS disciplining since there is no need for manual calibration.

All you need to do is connect your signal up to one of its inputs, power it up, select the appropriate input and averaging time, then wait a few seconds and read off the result.

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PIC16F1455-I/P – Kelvin the Cricket (Oct17), Microbridge (May17)

PIC16F1507-I/P – Wideband Oxygen Sensor (Jun-Jul12)

PIC16F88-E/P – Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14), Automotive Sensor Modifier (Dec16)

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PIC16LF88-I/SO – LED Ladybird (Apr13)

PIC16LF1709-I/SO – Battery Cell Balancer (Mar16)

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PIC18F4550-I/P – GPS Car Computer (Jan10), GPS Boat Computer (Oct10)

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PIC32MX170F256B-50I/SP – Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor* Micromite LCD BackPack (either version) (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Micromite LCD BackPack V2 (May17), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17)

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PIC32MX470F512L-120/PT – Micromite PLUS Explore 100 (Sep-Oct16)

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2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
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SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
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CLASSIC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
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LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
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PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SIGRADIO (INTEGRATED SOR) Main PCB	OCT 2013	06109131	$35.00
SIGRADIO (INTEGRATED SOR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
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BELLBIRD	DEC 2013	03112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
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4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15108151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$5.00
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MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
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PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
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MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$2.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
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6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017		$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
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DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SAFETY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$45.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00

NEW THIS MONTH

6GHz+ FREQUENCY COUNTER CASE PIECES (SET)	DEC 2017		$15.00
SUPER-7 SUPERHET AM RADIO PCB	DEC 2017	08111171	$25.00
SUPER-7 SUPERHET AM RADIO CASE PIECES	DEC 2017		$25.00

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Four quadrant power supply is based on high voltage op amp

This circuit resembles an audio power amplifier and indeed, it may be used as one. But since it's able to sink or source a substantial current of up to about 7A, at voltages up to around ±36V, it also makes a very handy power supply.

"Four-quadrant" indicates that it can sink or source current with either positive or negative output voltages.

It's based around IC1, an OPA453 high-voltage op amp. This can operate with supplies from ±10V up to ±40V. Its output (pin 6) can supply up to ±50mA to the load at CON4 directly via a 1kΩ resistor.

To increase the current capability, this output pin also drives a complementary pair of Darlington emitter-followers formed by NPN transistors Q1/Q3 and PNP transistors Q2/Q4.

Additional transistors Q5 and Q6 are effectively in parallel with Q3 and Q4 respectively, and further boost the output current capability.

It's possible to parallel more sets of transistors for higher output currents, assuming the power supply has the capacity. If you only need a few amps, you could omit Q5 and Q6 to save money and space.

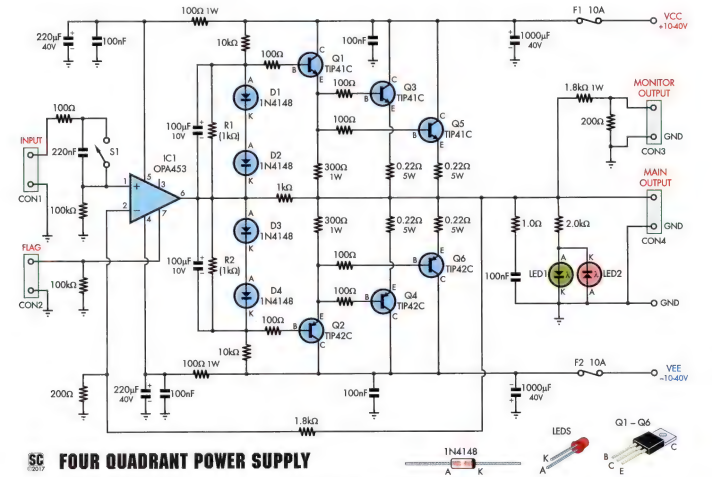
IC1 does not drive the base of Q1 and Q2 directly as this would cause glitches in the output when switching between sourcing and sinking current.

Instead, there is a base bias generating network consisting of small signal diodes D1-D4, 10kΩ resistors between these diodes and the supply rails, resistors R1 and R2 in parallel with D1-D4 and two 100µF capacitors, also across the diode pairs.

Most of the time, current flows from the V_{CC} rail, through the upper 10kΩ resistor, then through diodes D1-D4, the second 10kΩ resistor and out through the V_{EE} negative rail. This sets up a bias of around 1.2V across D1 and D2 and a similar bias voltage across D3 and D4.

The parallel 100µF capacitors are charged up to this potential and this helps preserves the bias for a short time if the op amp output swings near one of the rails.

In this case, the voltage across the associated 10kΩ resistor will be very low and so very little current will flow through the bias network, hence the need for these capacitors.



FOUR QUADRANT POWER SUPPLY

SC ©2017

By shunting some current around D1-D4, R1 and R2 reduce the bias voltage and it can be tweaked by varying their values.

Lower values (<1kΩ) will give lower quiescent current and higher values will give higher quiescent current and thus lower distortion for AC signals (to a point). Be careful not to make the values too high or thermal runaway could occur, damaging Q3-Q6.

The ~1.2V bias bases the base of Q1 to be around 1.2V above the op amp output, and the base of Q2 around 1.2V below the op amp output. This keeps the base-emitter junctions of Q1-Q6 forward-biased with around 0.6V each, causing a small quiescent current to flow through all these devices.

This quiescent current flows through the 300Ω emitter resistors for Q1 and Q2, and the 0.22Ω emitter resistors for Q3-Q6.

If the quiescent current increases, therefore, the voltage across these emitter resistors increases, reducing the base-emitter voltage of those transistors and therefore reducing the collector (and emitter) current. Thus these resistors provide negative feedback to stabilise the quiescent current.

It is possible to operate the circuit without the bias network, ie, remove D1-D4, R1, R2 and the two 100µF capacitors.

However, the op amp output will have to swing quickly between -1.4V and +1.4V when it transitions between sinking and sourcing current and so the output will not be as clean. However, this will reduce standing power consumption and dissipation in the components .

A Zobel network across CON4, comprising a series 1Ω resistor and 100nF capacitor, prevents oscillation due to the phase shift caused by the output buffer network. LED1 and LED2 are connected anode-to-cathode so that LED1 lights for a positive output voltage and LED2 for a negative voltage. The brightness of these LEDs increases with increasing output voltage.

CON3, the monitor output, is fed with a signal that is attenuated by a factor of 10 compared to the main output and is handy to feed to an oscilloscope for viewing.

The control signal is fed into CON1 and can come from an audio signal source, potentiometer wiper, etc. For DC control (eg, using this as a power supply), S1 should be closed. The input impedance is 100kΩ.

Feedback from the output to inverting pin 2 of IC1 provides a gain of ten. The minimum gain the OPA453 requires for stability is five. So if you connect a pot across a ±5V regulated supply and then feed the wiper signal to CON1, this will allow you to vary the output over the full ±37V (approximate) range. For AC use, the bandwidth is over 100kHz.

IC1 runs off the main V_{CC}/V_{EE} supply, however, it is decoupled using two RC low-pass filters of 100Ω and 220µF. This prevents ripple and noise from the main supply from affecting the op amp.

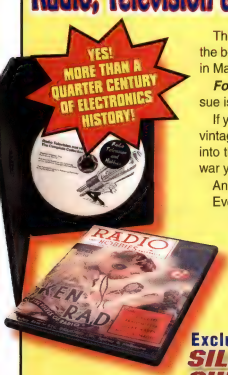
The Flag output, at CON2, provides a signal which indicates whether IC1 has shut down due to overheating.

Note that if you plan to use this feature to protect the unit against overheating, you would need to mount IC1 on the same heatsink as Q1-Q6, ideally in the middle and close to these transistors, and even then there would be no guarantee that it would trip before Q1-Q6 fail. It depends on many factors such as the gain of Q1-Q6.

IC1 comes in a 7-pin TO-220 package.

Petre Petrov,
Sofia, Bulgaria ($60)

Radio, Television & Hobbies: the COMPLETE archive on DVD



This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

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Micromite-based Air Conditioner Remote Control

This circuit allows us to turn on our upstairs air conditioner while we are still downstairs, to cool the sleeping area at night.

The air conditioner doesn't need to run all night; just long enough to cool and dehumidify the bedroom (or warm it up in winter). So the controller automatically turns it off either when a target temperature has been reached, or after a fixed delay, whichever comes first.

Our air conditioner has no remote control, just a control panel on the wall with an on/off button and some mode/thermostat control buttons hidden beneath a flip-down panel.

We rang the distributor to inquire about adding a remote control, however, all they offered was an expensive infrared module which would only work in line-of-sight. So we came up with our own 315MHz smart radio control circuit instead.

The circuit is based around a 28-pin Micromite (PIC32MX170F256B) chip, IC1. DS18B20 digital temperature sensor IC2 is connected to pin 14 with a 4.7kΩ pull-up/power supply resistor, allowing IC1 to monitor the temperature near the control panel.

A commercial 315MHz four-channel remote control receiver (shown below) is connected to pins 15-18 and pulls one of these low when one of the buttons on the associated remote (depicted) is pressed.

The LCD module shows the current room temperature at all times and also shows the remaining time and pre-set temperature once the air conditioner has been switched on.

It is connected in the usual way, with Micromite pins 4-7 driving the four-bit data bus (D4-D7) and pins 9 and 10 controlling the Enable and Reset inputs respectively. A 10kΩ resistor sets the backlight brightness while a 1.8kΩ fixed resistor sets the LCD contrast.

Pin 23 of the Micromite drives a 4.5V (nominal) reed relay, RLY1, which has its COM/NO contacts connected across the on/off pushbutton in the aircon control panel.

To turn the air conditioner on or off it simply pulses the relay for a short time to simulate a button press. Since the Micromite monitors the temperature, the only time we need to use the control panel is to switch between the heating and cooling modes.

Pressing button "A" on the remote (pulling pin 15 of IC1 low) causes the Micromite to turn the air conditioner on, assuming that the ambient temperature is not already at the target. Once the required temperature is reached, or the maximum on-time has passed, it will activate RLY1 again, switching the aircon unit off.

Buttons "C" and "D" adjust the target temperature up or down. Pressing these causes pin 17 or 18 of IC1 to be pulled low. The micro has internal pull-up currents enabled on these pins which normally keeps them high (at around 3.3V) but when the remote control receiver pulls them down to 0V, IC1 senses this.

Pressing button "B" (pulling pin 16 of IC1 low) adjusts the maximum on-time. Initially, this is half an hour and it increases by another half hour each time button B is pressed. It is reset to the initial half-hour time each time the unit switches the air conditioner off.

If button "B" is held down for more than three seconds, a menu is displayed on the LCD which allows you to control whether the piezo sounder (driven from pin 26 of IC1) beeps when the set temperature is reached and when buttons on the remote are pressed. This menu also lets you change the duration of these beeps.

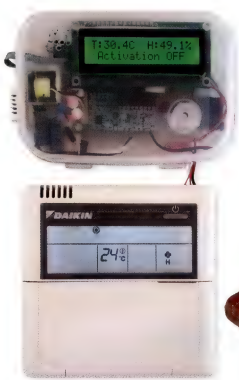
Power is from a 5V linear or switchmode supply and is reduced to 3.3V for IC1 by an MCP1700 linear regulator. Finally, LED1 flashes when a remote control signal is received and LK1 provides a method to disable the temperature read-out on the LCD.

A PCB design is available for this project and can be downloaded from the Silicon Chip website. The corresponding parts list for building the board is shown on the next page. Once built, the board will fit inside a small plastic box of 125 x 85 x 25mm.

Note that you can use a DHT22 temperature/humidity sensor in place of the DS18B20, as shown in the overlay diagram below. The software will then display both temperature and humidity.

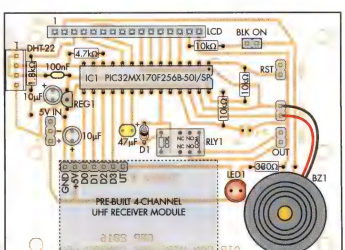
Two versions of the software are available for download from the Silicon Chip website. "telecontrol V1_1.bas" should be used if a DS18B20 sensor has been fitted while "telecontrol V1_2.bas" is for use with the DHT22.

Gianni & Charmaine Pallotti, North Rocks, NSW. ($90)

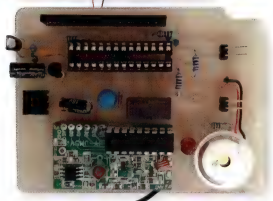


Right: PCB overlay for the aircon remote controller.

Below: the 315MHz remote control, which came along with a matching receiver.



The wires from the 4.5V relay are soldered in parallel with the power button on the aircon, denoted by the red circle on the photo. Not all aircons will have these pins in the same location.



The small receiver board for the remote is located at the bottom of the PCB, with the 16-pin female header used to connect a 16x2 LCD screen

Parts

1 single-sided PCB, code 06102171, 89 x 65mm
1 16x2 alphanumeric LCD screen
1 28-pin narrow DIL socket
1 4.5V DC coil reed relay (RLY1; AXICOM FX2 D3204 – available from au.element14.com)
1 3-12V self-oscillating piezo buzzer
3 2-pin male headers (CON1-CON3)
1 16-pin female header (CON4)
1 3-pin female header (CON5)
1 2-pin header with shorting block (JP1)
1 4-way 315MHz remote control receiver with key-fob transmitter

Semiconductors

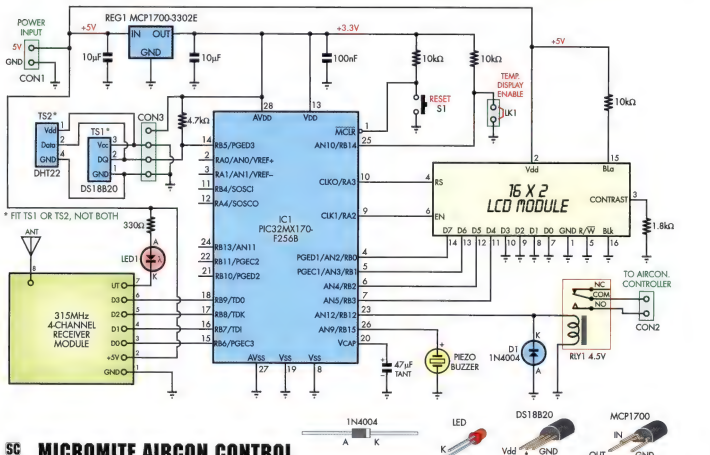
1 PIC32MX170F256B programmed with Micromite firmware (IC1)
1 DS18B20 digital temperature sensor (TO-92) (TS1) ***OR***
1 DHT22/AM2302 temperature & humidity sensor (Silicon Chip Online Shop Cat SC4150)
1 MCP1700-3.3 linear regulator (REG1)
1 5mm LED (LED1)
1 1N4004 1A diode (D1)

Capacitors

1 47µF 6V tantalum
2 10µF 16V electrolytic
1 100nF ceramic or MKT

Resistors (all 0.25W, 1%)

3 10kΩ 1 4.7kΩ 1 1.8kΩ 1 330Ω



MICROMITE AIRCON CONTROL

Vintage Radio

By Marc Chick

Roberts R66 4-valve 2-band Portable Superhet

Roberts is a British brand previously not often seen in Australia although Roberts DAB+ radios have been on sale in recent times. In essence, this is not a restoration story but a straightforward repair of a set that was in fairly good condition.

The styling of the R66 portable is interesting and apparently the inspiration for the design came from the leatherette handbags owned by the wife of Harry Roberts.

Interestingly, Roberts are now producing a range of retro DAB+/DAB/FM radios with similar styling although they are not available on the Australian market (see **www.robertsradio.com/uk/products/retro-radios**).

Introduced in 1956, the Roberts R66 is 4-valve set which can be run from 230VAC mains or batteries. It was unusual in using selenium rectifiers for the HT and LT (filament) supply rails and it also employed a ferrite rod antenna at a time when most equivalent Australian sets used a wound loop antenna.

The four battery valves are unique to European sets, having been manufactured at times by Philips, Mullard, Siemens and Telefunken, but the circuit itself is a conventional superheterodyne with two bands: MW and LW.

The first valve is a DK96 pentagrid converter which functions as a mixer-oscillator, commonly referred to as a frequency changer. Its intermediate frequency is 470kHz; somewhat higher than the 455kHz used in most Australian sets. V1's plate drives the first IF transformer.

The ferrite rod antenna circuit's bandwidth is evidently wide enough to tune both the MW and LW bands. The oscillator circuit is switched to cover the two bands using a large wafer switch.

The secondary of the first IF transformer drives the grid of V2, a DF96 pentode and its plate, in turn, drives the second IF transformer and this drives the grid of V3, a DAF96 diode-pentode which functions as the demodulator and audio preamplifier.

The audio signal from V3's diode appears across capacitor C19 is fed via the volume potentiometer R8 to the grid of V3. Its output is capacitively coupled to the grid of pentode V4, operating as a class-A stage with transformer T1 which drives the loudspeaker. There is no negative feedback, probably because the circuit did not have a lot of gain to spare.

The demodulated audio is also used to apply AGC back to the input grid of V1 and the control grid of V2.

The AC power supply uses selenium rectifiers as noted above. The HT supply is a half-wave rectifier involving MR1 and capacitor C28 to produce about 90V DC.

The filament supply is DC as well, involving two selenium rectifiers, MR2 & MR3 and three stages of filtering with resistors R15 & R16 and capacitors C29, C30 & C31. The resulting low ripple supply is essential for filaments (cathodes) of these battery valves, otherwise hum would be a serious problem when operating from the mains supply.

This particular radio had apparently come from the UK to Australia, after a long stint in South Africa. While it needed some repairs, its overall appearance was not bad for such a traveller although the leatherette covering was coming off in a number of places and the carrying strap was quite frayed. The leatherette was glued back as necessary but that was the extent of any cosmetic repairs.

Note that the dial on this Roberts set looks a little odd since it reads in metres rather than kHz. Hence the medium wave (MW) band ranges from 182 to 590m (or 508kHz to 1.68MHz) while the long wave (LW) band ranges from 900 to 2000m (150kHz to 333kHz).

In spite of its generally good appearance, any temptation to just power it up was resisted and the chassis was carefully inspected. One should always carefully inspect a radio foreign to you (not because it's foreign) and of unknown provenance.

There are often hidden dangers lurking, for those who fail to look. Never forget that most of these old radios were dumped when they had failed and were replaced with something

Electrolytic capacitor C30 is shown above with a leak that solidified on the top of its can.

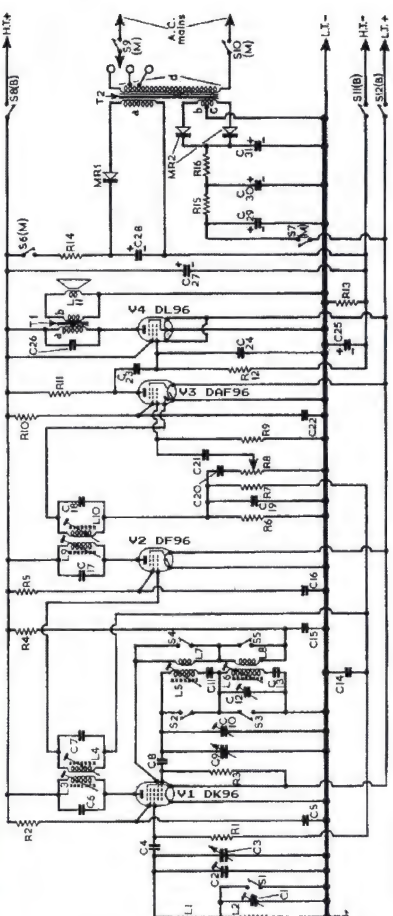
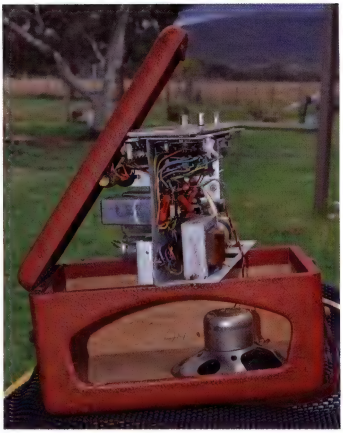


Fig.1: complete circuit diagram for the Roberts R66 radio. In this circuit, switches denoted with an (M) close for mains operation, while those with the suffix (B) close for battery operation, and are controlled by the leftmost knob on the radio. This knob also changes tuning over the MW or LW band, with switches S1, S3 & S5 closing for MW operation and S2 & S4 closing for LW. *Image source: Radiomuseum (www.radiomuseum.org/r/roberts_r66r_6.html); from the service sheet.*



Shown above is the radio seated in its upright "playing" position. The speaker is located behind the grille, as shown in the photo to the right.
The radio can run from either 200-250VAC mains or two dry batteries, one rated at 90V for HT and the other at 1.5V for LT.

much more modern, probably transistorised.

So I looked for any obvious tampering within the chassis, as well as the wire insulation quality. Then the mains and speaker transformers were checked. C30, one of the large electrolytic capacitors was leaking from the top of the can, so that was an immediate visual inspection fail. So powering up the radio was out of the question.

That capacitor and its mates, C29 & C31, all 2500µF 3V rated, were replaced and so were the rest of the electrolytics apart from C27 & C28 which was a twin capacitor (ie, two capacitors in one can).

They were checked for leakage and much to my surprise, they were comparable after a few minutes at 150V to a new 47µF 450V capacitor, drawing less than 1mA, so it was reconnected. The HT current is listed at 10.4mA.

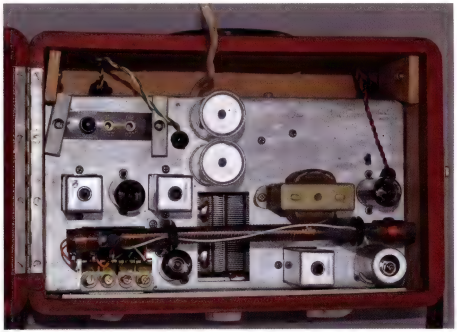
All the ceramic capacitors were fine but some of the resistors were replaced. Capacitor C14 (0.5µF paper) was lifted and tested at the closest voltage to its rating (350V DC) as I could apply with one of my insulation testers (250V DC). That gave a result of 700kΩ and so it was more of a resistor than a capacitor.

That would have the effect of shunting away the AGC signal which would otherwise be applied to the signal grid of V1 (DK96) and also to the grid of V2 (DF96).

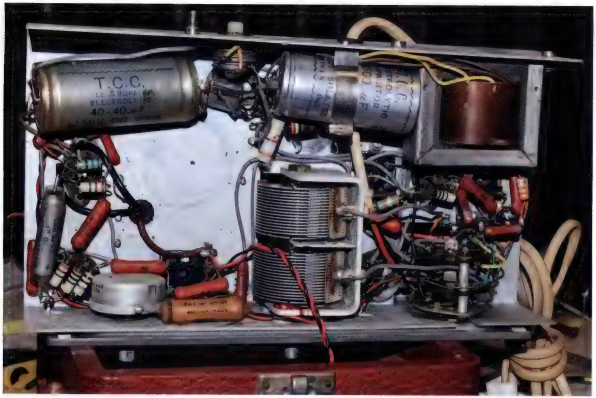
In addition, in sets like this, the control grids draw insignificant current and any leakage of positive voltage in coupling to the grid from a plate will impinge significantly on the bias. Anyway, the capacitor was replaced with a modern plastic dielectric type.

Powering up

I noted before powering it that it had 230VAC mains switching via wafer switches. Often that is a bad idea but at least with this set both Neutral and Active are switched separately



Opening the plywood case of the Roberts R66 shows the "top" of the chassis, including the ferrite rod antenna. L1 & L2 form the ferrite road antenna coils and are tuned via C3 as shown in Fig.1. The red/black wire is for the HT battery connections, while the yellow/green wire is for LT.



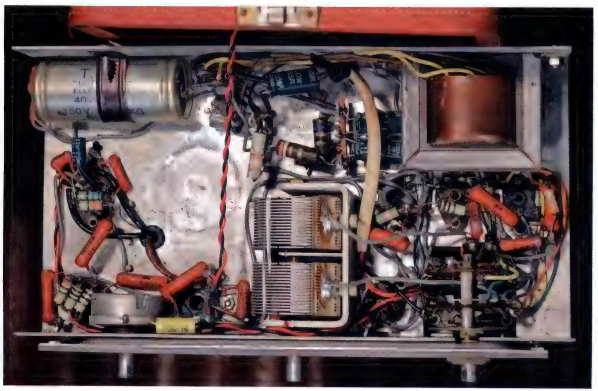
Shown left is the "bottom" of the chassis before restoration work had begun. Since the speaker is attached to the case, its leads need to be desoldered to completely free the chassis.

(ie, with a double-pole switch). The switching also provides for changeover to battery power.

The circuit diagram reveals that because the set uses battery valves, with directly heated cathodes, it is important that the filament supply has the correct polarity since it forms part of their grid bias. So one always needs to check to see that things have not been changed on this point.

Ultimately, after all the checks and component replacements had been completed, the set powered up without problems. Then it was on to check the alignment.

It would be folly to assume that the alignment would not have changed after 60 over years, and so it had. The MW coil had slipped on the aerial rod and both bands were out of calibration. They were re-adjusted to the manufacturer's specifications. Its performance is quite impressive. **SC**



The underside of the chassis after repair, with the replacement capacitors in place. All the electrolytic capacitors, except for twin capacitor C27/28, were replaced. All ceramic capacitors checked out OK and only a few resistors needed to be replaced.

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Energy Meter required to monitor whole house

Have you published an article on an Energy Meter that can be installed into the meter box which can log usage?

I am considering PV panels and/or some sort of battery system for my home but I'd like to calculate the economics of the exercise – I am not motivated by the feel-good factor.

Without a more detailed breakdown of my home's electricity usage (hourly), it isn't possible to know whether there is an economic benefit of installing panels or batteries. I have plenty of north-facing roof space with a high pitched roof which would be an ideal place to install panels.

The new WA government is discussing an end of government subsidy to Synergy (the state-owned electricity retailer) that allows them to sell electricity to the market (voters) below cost. This could see WA electricity prices rising about 15% in the short term.

With the falling prices of panels and storage solutions coupled with the rise in electricity supply costs, I believe that the economic benefit is becoming greater, although it probably still isn't economic when the life of the panels and batteries is considered.

I guess if I get desperate I could install a camera in the meter box to photograph the meter every 60 minutes and OCR the pictures! (W. H., Mt Pleasant, WA)

● Our latest Energy Meter, published in August-October 2016, is designed to monitor a power point and is rated at 20A. It is not suitable to monitor the entire meter box. For more information on this see **siliconchip.com.au/Series/302** (errata, November 2016: **siliconchip.com.au/Article/10441**).

Charging a gel cell (SLA) battery

I have a caravan that has a 120W solar panel charging a 100Ah deep-cycle battery. The caravan also has a smaller 7Ah gel cell battery for emergency braking, should the van and vehicle disconnect.

A release cable pulls a switch that applies power to the electric brakes. This battery last for approximately 15 minutes. This battery receives some charge from the vehicle whilst towing and can have an AC adaptor connected to charge whilst the van is connected to power.

My problem is that I don't tow it long enough or its not connected to power and so it doesn't keep this smaller battery charged. I have assembled a small buck/boost module to provide 13.5-13.8V to charge the 7Ah battery from the main battery. There is some electronics in the battery box, including a diode to prevent reverse flow. My questions are:

1) Is providing 13.5-13.8V continuously to the battery the best solution?
2) Should I just connect the main battery to the smaller one via the electronics and reverse flow diode?
3) Could I add another solar charge controller just for this smaller battery?

(G. H., Littlehampton, SA)

● It really depends on the buck/boost module and the amount of current this can deliver to the 7Ah battery as to whether it should be directly connected.

If you limit to a 1A charge then a 2.7Ω 10W resistor could be used to restrict charging should the main battery be discharged. The resistor should be inside a diecast box used as a heatsink, with wires exiting through a cable gland.

Having the buck/boost module powered from the solar panel and connected continuously to the 7Ah battery should be OK as charging current will drop to a trickle once the battery voltage reaches the buck/boost module output voltage.

Having the buck-boost module connected to the main vehicle battery is probably not ideal as it will discharge the main vehicle battery when it is not being topped up via solar power or vehicle engine charging.

You could add another charger for the 7Ah battery but what you have with the buck/boost module seems adequate.

LK6 in Currawong Stereo Valve Amplifier

I never got my Currawong up and flying when I built it two years ago and just the other day started fault finding. I discovered that the 100µF capacitor in the power-on delay circuit had high leakage and managed to fix it.

However, there is one thing that puzzles me. When looking at the schematic, LK6 actually shorts out one of the diodes in BR1 that supplies the 12AX7s with heater current. I have no plan other than to go without the link, but what is it for?

I also checked the modifications proposed in parts 2 and 3 of Currawong articles but cannot remember seeing something out of the ordinary. And I made all mods proposed. (M. K., Vänersborg, Sweden)

● There was a special note about LK6 on page 38 of the November 2014 issue. LK6 must not be fitted unless two separate 12V transformer windings are used, one to power the 6L6 heaters (between pins 1 and 3 of CON8) and one to power the 12AX7 heaters and power-on delay/headphone relay circuity (connected between pins 4 and 5 of CON8).

In that case, fitting LK6 connects V_{EE} to ground and will not short out BR1. See the October 2016 issue on pages 44-48, where we used this arrangement with a custom-wound transformer from Altronics which had the required extra windings. You can preview this article at: **siliconchip.com.au/Article/10298**

Retaining trigger output in DDS IF Alignment

I have a query regarding the Touchscreen DDS IF Alignment module in the September 2017 issue (**siliconchip.com.au/Article/10799**).

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

I have upgraded from the original DDS generator published in April 2017 and have kept the trigger output on the box. Does the upgraded software still use this trigger output or has it been disabled as it is no longer necessary? (M. McC., Kelvin Grove, Qld)

● To avoid the need for having separate connectors for the IF alignment detector input and trigger output, the DDS IF Alignment unit was designed to use the same pin (pin 24) as both the analog input for IF alignment and trigger output in the other modes. This was not mentioned in the article.

Since you already have both connectors, it would be possible to modify the software to use the original trigger output pin (pin 16) and use pin 24 as a dedicated analog input for IF alignment.

We have modified the BASIC code to allow this but have not tested it. If any readers want to try this, they can send us an email and we will supply this modified code.

Ignition system needed for Yamaha Jetski

I have a 1989 Yamaha WR500 twin-cylinder jetski. I am in need of a High-Energy Electronic Ignition for it. The original capacitor discharge ignition (CDI) boxes are not available anymore. Can you help me? (K. S., via email)

● We have published many ignition systems in the past. The most recent are listed below. Which one is suitable depends on the way the original ignition was powered.

Some CDIs have a high-voltage generator coil incorporated in the generator and this type of ignition may be replaced with the May 2008 Replacement CDI Module in most cases.

If the CDI was powered from the 12V supply then the High-Energy Ignition from November and December 2012 or the CDI from December 2014 and January 2015 would be suitable. These can be triggered by the reluctor, Hall effect or points or optical pickups.

Note that many twin engines fire both cylinders at once, so only one ignition system is required. This is a wasted spark system meaning that when one cylinder is fired on the compression stroke, the other cylinder spark is "wasted", as it is not at the right stage for firing (either the cylinder is near its lower position with a two-stroke, or at the exhaust stroke in a four-stroke).

- December 2014 & January 2015: High-Energy Multi-Spark CDI For Performance Cars by John Clarke, PCB code 05112141 (available from the SILICON CHIP online shop); see siliconchip.com.au/Series/279
- November & December 2012: High-Energy Ignition System for Cars by John Clarke, kits: Jaycar KC5513 & Altronics K4030, PCB code 05110121 (available from the SILICON CHIP online shop); see siliconchip.com.au/Series/18
- May 2008: Replacement CDI Module for Small Petrol Motors by John Clarke, kits: Jaycar KC5466, PCB code 05105081 (available from SILICON CHIP online shop); see siliconchip.com.au/Article/1820

Sourcing 8-gang pots for 3-Way Active Crossover

Firstly, I wanted to say thanks for the PCB and panels for the Active Crossover from the September and October issues (siliconchip.com.au/Series/318), which all arrived.

I am starting to compile the components and am having a problem trying to order the Bourns PTD90 potentiometers.

If I try to enter the full part number from the parts list in your article, the Bourns website says no results. It will show the correct looking pot if I just enter PTD90 but requires a lot more info to input in order to get the right one.

Is it possible the part number in your parts list is incorrect? (D. Y., Nelson, NZ)

● The part number given is correct although it may be written PTD908-1015F-B103 (ie, with two added dashes) and that may be why the search was coming up blank. We sell a pack of these pots with knobs in our Online Shop, at siliconchip.com.au/Shop/7/4408

They are also available from Mouser; see siliconchip.com.au/link/aag9

Ultrasonic Anti-Fouling with leaky capacitor

I built the two-channel version of the Ultrasonic Anti-Fouling for Boats Mk2 from the Jaycar kit (KC5535), based on the project published in the May and June 2017 issues (siliconchip.com.au/Series/312). I have not yet installed it in my boat as there is an issue with starting the unit.

When first switched on, the green LED comes on for about two seconds, then the fault LED flashes and remains in this state indefinitely. If I turn the power off, wait until the fault LED stops flashing and then turn the power on, the unit runs as it should.

Even with a delay of around 20-30 minutes, it starts fine. But if I leave the unit off for a longer time (an hour or so), it reverts to the fault condition.

Whilst running, I have set up and checked the under-voltage lockout threshold and hysteresis. It all works as it should.

I am quite an experienced electronics builder and have fully checked that I have not placed any components wrongly, bad solder joints etc. Once started, the unit runs perfectly and I have had it run for days. Do you have any solution for me? (D. B., Sydney, NSW)

● It seems that the unit has excessive leakage with one (or both) of the low-ESR 2200µF capacitors, during the soft start sequence. The leakage will be more apparent when switching on the power after the capacitors have fully discharged, ie, after it has been off for a while.

To verify this, remove one capacitor and check if the circuit starts up. If it does, then the one which was removed

Can IF Alignment project be use for FM receiver alignment

I have a question regarding your 455kHz DDS IF Alignment project which was published in the September 2017 issue (siliconchip.com.au/Article/10799).

I checked the original Touchscreen DDS Signal Generator article that the project was based on (in the April 2017 issue) and it says it can create sinewaves to 10MHz. Would it be possible to set this up for 10.7MHz IF alignment as well as 455kHz? (J. G., Mt Helen, Vic)

- It could work in theory but the software as provided does not allow it. The DDS module's clock runs at 25MHz so it should be capable of generating sinewaves up to 12.5MHz. In practice, distortion is already pretty high at 10MHz and climbs above that.

However, this may not be a major issue for IF alignment since the harmonics will be well outside the IF bandwidth.

The main obstacle is that the original signal generator code from Geoff Graham, which we used as a basis for the IF Alignment project, has a built-in limit of 10MHz.

This seems to mainly be due to the number of digits displayed in the frequency field.

You could change the provided code by searching for all instances of "9999999" (ie, 9.999999MHz, the maximum) and change them to "10999999".

This may allow you to set a centre frequency of 10.7MHz but we suspect the display would be wrong (the top digit could be cut off).

Still, it might be worth a try. It could possibly be made to work with a little extra software tweaking.

is leaky. If not, try removing the other one and see if it starts then. Replacing the capacitor(s) should allow the unit to start normally.

If you are prepared to still use the leaky capacitor(s), you could add a resistor across the drain and source of Q5 to counteract the leakage so the circuit will start up even after the capacitors have fully discharged. A 330Ω 1W resistor should do the trick.

Programming EEPROMs

Could the Microbridge (May 2017; siliconchip.com.au/Article/10648) be used with an adaptor to program EEPROMs? If yes, will pic32prog do the job, or what program would you recommend? I need to burn an A25L80P chip for a PC motherboard. (I. T., Blacktown, NSW)

- pic32prog is only designed for programming PIC32 chips. The easiest way to program EEPROMs is to buy a TL866CS programmer. They're only about $45 including postage. A25L80P is listed among its supported chips. Just do a google search for TL866CS and you'll find plenty of sellers on eBay and AliExpress.

A correspondent who is very new to electronics

Hello! I recently purchased the Digital Audio Delay kit (KC5506) from Jaycar, which was published in your December 2011 issue (siliconchip.com.au/Article/1235) and I'm told you're the people to ask advice from. I hope that's true!

When I bought the kit a couple of weeks ago, I thought there'd be a small amount of soldering – I had no idea it would be as intense as it is. I'm fine at soldering but lost when it comes to electronics.

So I decided I could put together the majority of it simply by copying the overhead view picture of the completed PCB in the instruction pages.

This has been fine so far, except it's an average quality black-and-white reproduction so sometimes it's hard to see things. This is where I need advice. The ICs seem to have matching "riser pads" underneath (I'm sure this is the wrong terminology). For instance, IC5 (74HC00) and the two nearby chips, IC3 and IC4.

I found the actual ICs in the kit but there are other pieces which exactly match their outline and which seem to fit together. But I see nothing about them in the instructions and the photo and diagram don't show them.

If they are supposed to fit together, do they need to be soldered together, or are they just supposed to click together? The same goes for all the other ICs as they all seem to have matching risers.

I have another question about identifying a part. There's an area with the labels "5V" and "3.3V", with "LK1" nearby too – the area is allocated three holes. The images and info in the plans just isn't enough for me to be confident I've got the correct piece.

I've found one part in the kit which is a strip of black plastic with three pins through it. Is that the right part? Which way up does it go – with the long legs upright, or the short legs upright? I'm sorry I'm so terrible at terminology.

I hope I make some semblance of sense. Thanks in advance for being gentle with me! (S. J., via email)

- The parts you are asking about in your first question are the IC sockets. They are mentioned in the instructions in the third paragraph under the heading "Through-hole parts" (on page 36 of our December 2011 issue).

You solder the sockets to the PCB, with the notches in the same position as the notches shown in the chips in the overlay diagram, Fig.6.

Then, once you've finished soldering everything, you straighten the pins of the ICs (either using a special tool you can buy at Jaycar or using longnose pliers) and push them into the sockets.

The sockets are a tight fit so they hold the chips in place and form good electrical contacts but you can still remove them later if you need to. It just takes a bit of pulling.

The main thing to be careful of when plugging the chips into their sockets is to ensure that none of the legs get folded up under the chip when you're pushing it into the socket.

And if you do remove them, you need to pull evenly at either end to avoid bending the pins (you can also get a special puller tool to do this which we recommend you use).

The likely source of your confusion is that we don't show the sockets in Fig.6. This is done for two reasons: one, because it would clutter up the diagram and two, because you can solder the ICs straight to the board if you want to.

That does improve long-term reliability but makes it very difficult to remove a chip if it goes bad, or if it's soldered the wrong way around, or if two are swapped etc.

Regarding your second question, that is the correct part and it's a three-pin male header. This is soldered to the board with the long pins sticking up and the short pins through the holes. Once in place, you can then plug a shorting block (which should also have been supplied) across two of the three pins.

Depending on which two you bridge, this selects either a 3.3V or 5V supply for the TOSLINK receivers. The labels on the board indicate which end to insert the jumper for either supply option.

Varying Pre-champ gain

I recently purchased the Jaycar Pre-champ Preamplifier kit (KC5166) based on the article from July 1994. I'm using it to boost the output signal of my guitar pickups, so I have inserted it after the volume pot.

Which resistor can I replace with a trimpot to reduce the amplification so the signal coming out isn't so "hot"?

I need some control over the output impedance, otherwise, it clips most interfaces or amps I use it with. It is a killer little design and works perfectly for my application because it doesn't colour the tone.

Or do you have some other suggestion of a design that would suit my purpose that you currently make? I want something active that will run from a 9V battery. (J. R., via email)

- The 2.2kΩ resistor between the emitter of Q1 and collector of Q2 can be replaced with a 2kΩ trimpot, connected as a rheostat (variable resistor), to vary the gain. Alternatively, you could connect a 1kΩ trimpot in series with the 100Ω resistor, again wired as a rheostat.

How to program various micros

I have been programming PICs and PICAXE chips with a Windows 98 computer which has now died. I tried using Google to find another way to program them as I couldn't get the software to work in Windows XP.

There's so much stuff out there that I really don't know what's best for me. I'm a retired dabbler and only have basic computer knowledge. Could you please suggest a device I could use. (G. A., Salisbury Downs, SA)

- As you have found, it is quite difficult to program micros using old Windows computers. It does not matter whether you want to dabble in micros or devices such as Arduino, Raspberry Pi or our Micromite, you are still going to need a much more recent model computer.

For the long term, you probably should consider a newer Windows machine – perhaps a secondhand laptop.

We use the PICkit 3 to program PICs, either via an in-circuit serial programming (ICSP) header or using our PIC/AVR Programming Adaptor Board design which was published in the May and June 2012 issues (siliconchip.com.au/Series/24). We also sometimes use a TL866a "MiniPro" programmer which can program almost any chip. It has a 40-pin ZIF socket and is supplied with Windows software.

For programming PICAXEs, we normally use the official PICAXE USB programming cable which is available from Altronics (Cat Z6198).

Crazy cricket is not quite right

I have built a number of these fun kits as published in the June 2012 issue (siliconchip.com.au/Article/638) and they all work properly as designed. However, one unit has a curious fault in that the life of its CR2032 battery is very short before becoming essentially flat, yet the other units have a good long life.

The only modifications that I've done is to replace the red LEDs with blue LEDs.

Can anyone offer any ideas as to why one unit has such a high current drain? I have extensively gone over both boards and there are no errors, and all components are correct. Could the PIC itself be causing the problem? (F. S., Ingham, Qld)

- Make sure the PIC12F675 is programmed correctly with the fuses in the Program Configuration Register as shown here:

```
__CONFIG _CPD_OFF & _CP_
OFF & _BODEN_OFF & _
MCLRE_OFF & _PWRTE_ON
& _WDT_ON & _INTRC_OSC_
NOCLKOUT
```

There could be a short on the PCB causing the high current or leakage due to a contaminated PCB such as oils or fluids spilt on the PCB. Give it a good clean with methylated spirits and see if that helps. Other problems could be with the PIC12F675 itself; it might have an internal fault causing a high current drain.

GPS-Based Frequency Reference queries

I am planning to construct the GPS-Based Frequency Reference from the March and April 2007 issues, with improvements published in the May

Charging LiFePO4 cells

The article by Jim Rowe in the August 2017 issue on Li-ion batteries and chargers (siliconchip.com.au/Article/10763) was informative, but I prefer $LiFePO_4$ cells for several reasons including improved safety and the fact that the operating voltage range matches perfectly the Micromite.

Are you going to do a similar article on low-power chargers for $LiFePO_4$ cells? (A. B., Manly, Qld)

- $LiFePO_4$ cells are very similar to other Li-ion cells except for the fact that they use $LiFePO_4$ as the cathode material. Different cathode materials were discussed, if briefly, in the article you refer to.

$LiFePO_4$ cells can be charged in the same way, using the CC-then-CV protocol. The only real difference is that the CC charging current should be restricted to 0.5C and the switch to CV charging made when the cell voltage rises to 4.0V; the cell voltage should not be allowed to rise beyond 4.2V.

Many low-cost lithium battery chargers do provide for charging $LiFePO_4$ batteries while others could probably be modified to meet these requirements.

We published an article on this technology in the June 2013 issue, titled "Get a LiFe with $LiFePO_4$ Cells". You can see a preview at siliconchip.com.au/Article/3816

Library problem compiling Arduino Data Logger sketch

I am building the Arduino Data Logger from the August and September issues (siliconchip.com.au/Series/316). Thank you for another interesting project.

I have finished the shield PCB so I downloaded the latest Arduino IDE 1.8.4 and downloaded the Arduino Data Logger software v1.0.

I unzipped the download and there were two directories: sketch and libraries. I loaded the six library zip files and then opened the sketch and tried to compile it. But I got the following error message:

Arduino_Data_Logger.ino:18:20: fatal error: RTClib.h: No such file or directory
#include "RTClib.h"

I tried two different computers but still got the same error message. Do you know what has gone wrong? (R. S., Epping, Vic)

● It seems like you may have an old, incompatible version of the RTClib library on your system(s). The only way we can reproduce this error message is to delete the RTClib library. Installing the library provided in our download then allows the sketch to be compiled.

Please check your "This PC\Documents\Arduino\libraries" directory and ensure there is an RTClib subdirectory.

If so, delete it and re-install the libraries we have supplied. You should be able to compile the Data Logger sketch then.

2007 and September 2011 issues (siliconchip.com.au/Series/57). My question is whether it is possible to use a different GPS receiver module than the one specified.

I have one u-blox Neo-7M module and one VK2828U7G5LF module. Before building the PCB I loaded the HEX file (GPSFrqv3.HEX) into a PIC-16F628A on bread board and injected 10MHz on pin 16 (CLK IN).

I fed the NMEA data from a GPS module (TIME and DATE) to pin 7 (RB1). On the LCD I have the UTC TIME decoded correctly but the DATE is always 00:00:00.

The Fix indication is fluctuating from Fx to Fx9. On pressing S1 (View Fix), the LCD shows:

Lat: 00:00.0000 0
Lng: 000:00.00000

On pressing S2 (View ANTH), the LCD shows:

Ant 3.6 m abvMSL
Sats in View: 00

On pressing S3 (View SATS), the LCD shows:

00:00dB 00:00dB
00:00dB 00:00dB

On pressing S4 (INIT GPS), the LCD displays:

Initializing GPS
RX module now

Any comments? (V. B., Greece)

● You should be able to use either of those GPS receiver modules in the GPS-based Frequency Reference, although it would be a little easier to use the V.KEL VK2828U7G5LF module since it is already provided with a 1pps output ("P").

With the u-blox Neo-7M module, you'd need to perform minor surgery to solder a wire to pin 3 of the Neo-7M chip, in order to obtain a 1pps output.

This is a little tricky, but it can be done if you're careful. The location to solder is shown in El Cheapo Modules part 10 on GPS receivers by Jim Rowe (October 2017; siliconchip.com.au/Series/306).

It's not easy to tell whether the results you were getting with your lashup are correct. It would be better to build the complete Frequency Reference and then see if you can decode all of the data.

Regardless of which GPS module you use, it should be located close to a window so that the patch antenna has a reasonable view of the sky. Otherwise, it won't deliver usable NMEA data or correctly locked 1pps pulses.

Unsure if RapidBrake is working properly

Thank you for the quick delivery of the parts which I ordered for the RapidBrake project. I have one query and one comment.

Everything went together beautifully. All the calibration settings were easily made to almost exactly the voltages specified. Step 6 and step 7 were done and LED1 flashed and the relay switched on and off exactly as it should until the jumper on JP3 was removed. Then it did nothing at all.

I have now installed the unit in the car with the jumper still in place and it works perfectly. What did I do wrong?

The polycarbonate adjustment jig is OK but the slots are cut just a bit too wide. Despite not having even peeled off the protective paper coverings, the assembled jig is very sloppy, it wobbles and falls apart at the least movement. I ended up sticking it all together with Blu-Tack.

The spacing between the two arms on which the box rests is the same as the distance between the mounting holes for the nylon spacers.

Thus the heads of the screws which hold the spacers to the box tend to sit on top of the jig arms, making it difficult to get them to sit cleanly at the correct angle.

You could have made the jig arms a little closer to each other, or I could have used countersunk screws.

Thanks for a great magazine filled with interesting and informative articles. (T. T., Woorim, Qld)

● JP3, when inserted, allows for calibration using the Earth's gravity as a reference. When JP3 is removed, the RapidBrake compensates for road slope so it is no longer activated due to gravity being at an angle (ie, when on a slope).

So after JP3 is removed, you will find that tilting the RapidBrake will not cause the relays to switch and this is correct.

It is only when mounted in a vehicle which is braking, with deceleration is in the same plane as the RapidBrake PCB, that the relays will switch at the required calibrated forces.

By successfully achieving calibration, you have already tested the RapidBrake's operation. JP3 should be removed for normal operation. You can only test the RapidBrake then by braking hard and watching the indicators.

Thanks for your comments regarding the jig. We will adjust the next batch we make to solve these issues. SC

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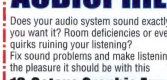

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Next Month in Silicon Chip

Arduino LC Meter Shield

This kit from Altronics is based on Jim Rowe's project in the June issue but has some changes to make it even easier to use. It can be built into the Mega Box which we described this month, or into a separate laser-cut case.

nRF24L01+ 2.4GHz Wireless Data Transceiver Modules

Jim Rowe describes the operation of these 2Mbps digital radio modules with software that lets you communicate with a pair of Arduino or Micromite modules. This article was held over in favour of the GY-68 and GY-BM modules in this month.

Easy-to-build Theremin has ten transistors

The eerie sound of the Theremin has featured in many movies from the distant past right up to the present. Why not build this latest design from Silicon Chip which was first published almost 50 years ago? That means it uses cheap and easy-to-get transistors and other bits (and no SMDs). You can take it to your next musical gig.

Touchscreen Controller for Induction Motor-based Lathes

This project uses a Micromite LCD BackPack along with our Induction Motor Speed Controller to drive a lathe. It works with Induction Motors that have separate Start and Run windings and provides the ability to reverse the motor as well as control and monitor its speed.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The January 2018 issue is due on sale in newsagents by Thursday, January 4th. Expect postal delivery of subscription copies in Australia between January 2nd and January 16th.

Notes & Errata

50A Charger Controller, November 2016: there is a discrepancy between the circuit and PCB design. The circuit shows D4 connected between ground and the junction of the 100kΩ and 22kΩ resistors, but on the PCB it is connected to the wrong end of the 100kΩ resistor. We suggest constructors cut the track and fix this with a wire link. The next batch of PCBs will have this flaw corrected.
Deluxe Touchscreen eFuse, July 2017: the text on page 47 (last paragraph, third column) states that IC4 is connected... after D7. Instead, it is connected after D1 and the associated 1Ω resistor.
Universal Battery Valve Power Supply, August 2017: the circuit on page 35 shows the labelling on diodes D4 & D5 swapped. In other respects, the circuit is correct.
3-way Active Crossover for speakers, September & October 2017: the PCB has pads for diode D4 but it was not shown on the PCB overlay or the circuit diagram because it isn't strictly needed. It can be left off or fitted below D3 if desired.
Kelvin the Cricket, October 2017: The circuit on page 44 shows switch S1 connected to pin GP0/pin 7. It should connect to GP2/pin 5. The PCB is correct.
Modifications to Universal Battery Valve Power Supply, Circuit Notebook, October 2017: there is a mistake in the circuit diagram which shorts out the secondary of transformer T2 by joining pins 5 and 8. Diodes D5 and D6 should connect to pin 5 of T2 only while diodes D4 and D7 and the 470µF capacitor connect to pin 8 of T2.
6GHz+ Touchscreen Frequency Meter, October-December 2017: in the first article on page 33 of the October 2017 issue, the parts list states that the 1PS70SB82 UHF diodes are supplied in the SOT-23 package. They are actually in the smaller SOT-323 (SC-70) package. The board is designed to accept this.
Super-7 AM Radio, November 2017: there are two errors on the circuit of page 49 & 49. Schottky diode D1 should be a BAT46, not BAT56. The capacitor connected to the emitters of Q6 & Q7, the output coupling capacitor, is 470µF, not 100µF. Also the parts list shows Q7, a BD140 as an NPN type. It is PNP, as shown correctly on the circuit.
Finally, the text on page 47 has errors in two sentences: "It oscillates at a frequency set by the parallel resonant circuitry connected to its emitter, ie, the primary of T3 plus VC3 and VC4" and "the output signal of the mixer/oscillator appears at the bottom end of this secondary and is fed to the primary of transformer T2". The first sentence should refer to T2 while the second should refer to T3.

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